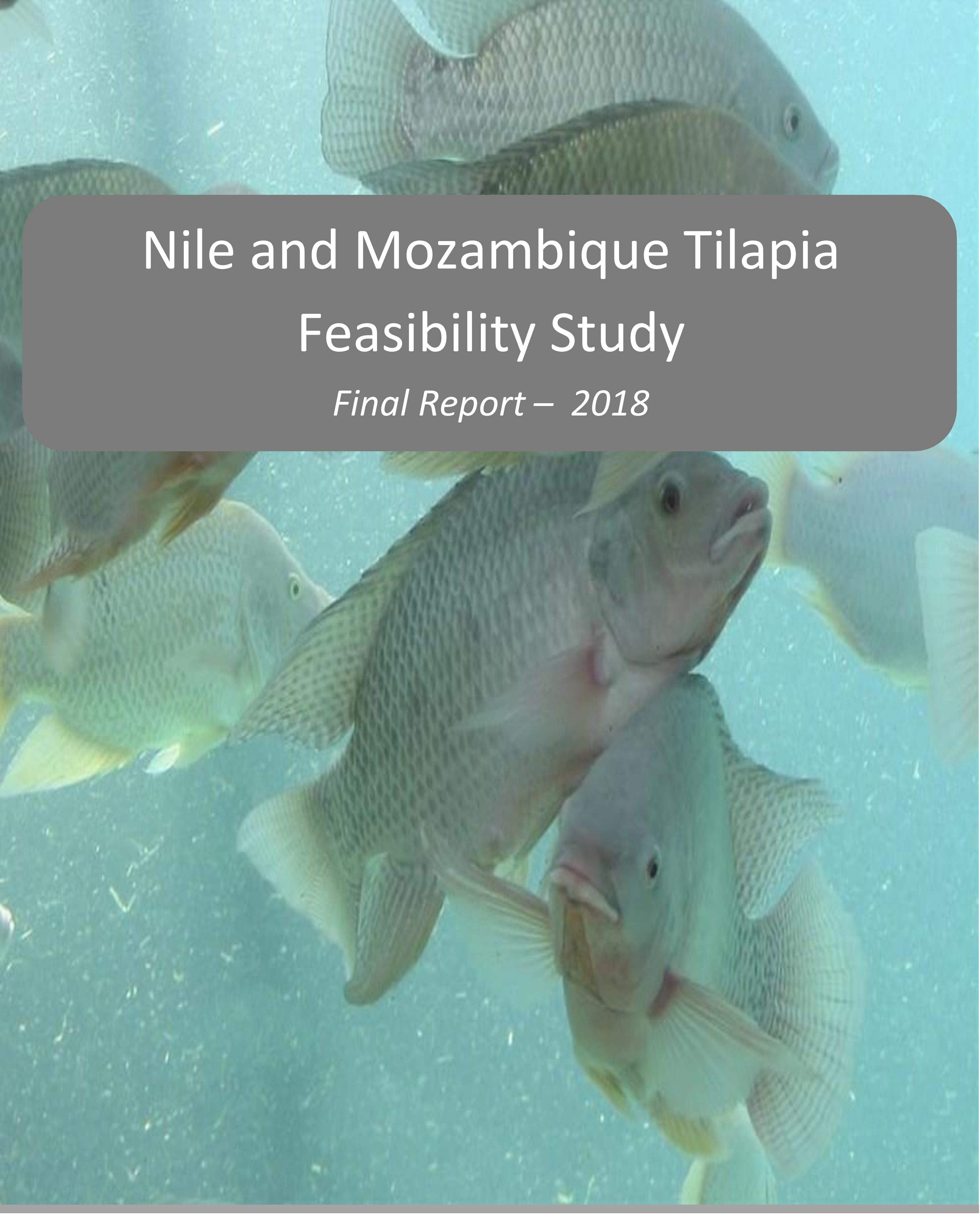

Nile and Mozambique Tilapia Feasibility Study

Final Report – 2018

agriculture,
forestry & fisheries

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Executive Summary

The Department of Agriculture, Forestry and Fisheries (DAFF) Chief Directorate: Aquaculture and Economic Development aims to "*develop a sustainable and competitive sector that will contribute meaningfully to job creation, economic development, sustainable livelihoods, food security, rural development and transformation"* in South Africa. In line with this mandate, research and development has been done on several freshwater and marine species which are important and valuable species to the South African aquaculture sector. The South African aquaculture industry can be divided into two sectors, namely marine aquaculture, and freshwater aquaculture, however for this report, Nile and Mozambique tilapia will be the freshwater species under consideration.

Oreochromis niloticus (Nile tilapia) and *Oreochromis Mossambicus* (Mozambique tilapia) are important freshwater species to the South African aquaculture industry as they offer several attributes that make them popular and attractive as a culture species. These attributes include:

- Hardiness and adaptability of a wide range of culture systems and environments,
- Relatively high disease resistance,
- Strong potential for widespread consumer appeal,
- Mozambique tilapia have a good tolerance for salinity, and
- Nile tilapia are fast growing and are considered to be the most economically viable tilapia species.

In South Africa, Nile tilapia are considered an Alien Invasive Species (AIS), and as a result are classified on the NEMBA Category Two (2) species list which requires tilapia producers to apply for national and provincial permits. Mozambique tilapia are indigenous to South Africa and require provincial permits to be issued for aquaculture operations.

Nile and Mozambique tilapia have a few key differences that impact on the choice of tilapia species for aquaculture. The two major differences identified is the growth rates and production cycle length, with Nile tilapia reaching an average size of 500 grams over a nine-month period and Mozambique tilapia reaching an average size of 475 grams over a fourteen-month period under ideal production conditions (i.e. optimal temperature, water quality, feeding etc). The faster growing Nile tilapia is the preferred species for aquaculture operations as it is more profitable, however the permits and regulations associated with Nile tilapia can be problematic for producers in South Africa. The Nile tilapia species has benefitted from genetic testing that focused on identifying the 'wanted' or ideal traits required which allowed for the improved and faster growth rates for aquaculture, which in time could be applied to increase the growth rate of the Mozambique tilapia (Urban-Econ, 2014).

Nile and Mozambique tilapia are well suited to several production systems including recirculating aquaculture systems (RAS), pond culture, aquaponics, and cage culture. Globally pond culture is the most commonly utilised system for tilapia production, however, in South Africa, Nile tilapia production is promoted in production systems that are low risk with regard to the spreading of Nile tilapia.

Currently, China, Indonesia and Egypt are the leading producers of Tilapia, while South Africa is reliant on Tilapia imports for both local consumption and redistribution into other African countries. The South African production and trade of Tilapia is limited due to factors such as unsuitable environment temperature regimes, an underdeveloped Tilapia value chain and high production costs. The need for increased focus on product development and marketing strategies has been identified, if South Africa wishes to compete at a regional and international level (Britz & Venter, 2016).

The following production guidelines provided in the table below gives a brief overview of a few important factors that should be considered when looking at Tilapia production in South Africa.

Nile and Mozambique Tilapia Production Guidelines

Optimal Temperature Range	28 – 36 °C
Water Conditions	Optimal pH: 6 - 9 Oxygen: 4 – 6 mg/L Ammonia: Less 2 mg/l NH_3-N Nitrites: Less 5mg/l NO_2-N
Average cost of fingerlings	Nile – R 2-00 (50-gram fingerling) Mozambique - R 1.75
Feed Price	R 12-00/kg
Stocking density	• **RAS:** 20 kg/m³ • **Pond:** 1.5 kg/m² • **Cage:** 53 kg/m³
Typical Survival rate	Nile – 85% Mozambique – 95%
Typical Feed Conversion Rate (FCR)	Generally, very efficient FCR achieved with cultured Tilapia 1:1.4

The generic economic model for Nile and Mozambique tilapia was developed through inputs from technical experts, industry stakeholders and peer-review workshops. Key assumptions used in the model are mentioned above, as well as several other production and system related assumptions were incorporated into the model. **An example** of the generic economic model results is illustrated in the table below.

Example: Financial Analysis: Nile tilapia in a Pond System

Production and Financial Assumptions	
Province	Limpopo
System	RAS
Species	Nile tilapia
Average Farm Gate Price	R 74/kg
Minimum Profitable Scale	34 tons
Selected selling weight	465 grams (8 months)
Target market	Local Market
Applicant details	Start-up farmer with existing land, no infrastructure, or facilities
Education level	Formal Education (certificate, diploma, degree)
Finance option	Debt/Equity (20%)
Interest Rate	8.25%
Generic Economic Model Results	
Total Capital Expenditure	R 9 689 071.24

Working Capital	R 1 925 265.82
Infrastructure expenditure	R 7 763 805.42
Profitability Index (PI)	1.02
Internal Rate of Return (IRR)	7%
Net Present Value (NPV) over 10 years	R 9 922 775

Based on the table above, a RAS system is profitable for Nile tilapia production when producing 34 tons of fish per annum and selling at a price of R 74/kg. A positive PI of 1.02 was achieved, with an IRR of 7%, indicating good investment potential exists. Pricing and economies of scale play a key role in determining the scale and profitability of an operation a

Based on the generic economic model results for both Nile and Mozambique tilapia, it was clear that Nile tilapia is more economically viable of the two species, which can be attributed to its improved growth rate, and shorter production cycle, thus making it a more feasible species for aquaculture production in South Africa. Gauteng, KwaZulu Natal, the Eastern Cape and Western Cape were identified as the most profitable provinces for Nile tilapia production when using any of the four (4) systems, while for Mozambique tilapia, Limpopo and Mpumalanga were the most profitable provinces when selecting cage culture or aquaponics. The Northern Cape was the least profitable province for both Nile and Mozambique tilapia production. The financial analysis indicates that all four (4) production systems (RAS, pond, cage culture and aquaponics) are feasible for tilapia production in South Africa, however, key factors such as the location of the aquaculture operation, targeted selling price and scale of production have a key influence on the feasibility and profitability of an operation.

Disclaimer: *Production information and assumptions in this report may be subject to change over time as certain production variables can be expected to fluctuate. Technical assumptions were utilised from various industry experts and stakeholders. Due to the sensitive nature of information shared by stakeholders, personal details of stakeholders will not be included in the report. Stakeholders will be referenced as "Personal Communication" in the document, and reference list.*

Table of Contents

Table of Figures

List of Tables

1. Introduction

1.1. Project background

In South Africa, aquaculture has been identified as a key economic sector and employment cluster. Various policies, programmes and initiatives have been developed and implemented to assist with the development of the aquaculture sector, some key initiatives include the National Aquaculture Strategic Framework (NASF), the Aquaculture Development and Enhancement Programme (ADEP), and Operation Phakisa to name a few. The primary goal of the various policies, programmes and initiatives is to accelerate the growth of the aquaculture industry, which will allow it to play a critical role in supplying fish products both locally and internationally, improving job creation, and contributing to the national economy, among other aspects. The sector has also been identified as a key industry that can impact the development and reindustrialisation of the rural communities and townships in South Africa.

Aquaculture is one of the fastest growing food sectors in the world, however the South African aquaculture sector remains small and underdeveloped despite the high-growth potential offered by the sector. In recent years, South Africa has seen improved access to aquaculture technology, increasing amounts of research and development, as well as government support from several key government departments. Coupled with the increasing support and interest in the South African aquaculture industry, there is potential to overcome some key challenges faced in the industry which slow down the development of the industry. These challenges include access to suitable production areas, production challenges, market access, and the need for value chain development.

Through continued research and development, value chain development, education and skills development and continued support, the South African aquaculture industry shows good growth potential that will prove to be valuable from an economic and social aspect.

This report focuses specifically on Nile and Mozambique tilapia production in South Africa, and considers the following potential production systems:

I. Recirculating Aquaculture Systems (RAS),
II. Pond culture,
III. Cage culture, and
IV. Aquaponics.

1.2. Purpose of the feasibility study

The feasibility study aims to provide guidelines and background information on the production of Nile and Mozambique tilapia in South Africa to assist producers and relevant stakeholders with a clear understanding of the industry itself. The study covers the following aspects:

I. Species Overview,
II. Biological and physical characteristics,
III. Geographical distribution in South Africa,
IV. Potential production systems,
V. Global, regional, and local market analysis,
VI. SWOT Analysis and mitigation measures,
VII. Production system financial analysis,
VIII. High level cost-benefit analysis,

IX. Best case scenarios for Tilapia production in South Africa, and
X. Recommendations for the Tilapia industry in South Africa.

In addition to the feasibility study conducted, generic economic models were developed for Nile and Mozambique tilapia. The generic economic models are aimed at assisting the DAFF, industry stakeholders, role-players, and new entrants to the Tilapia industry to determine the financial viability of Tilapia projects in South Africa.

1.3. Feasibility Study Outline

The feasibility study is made up of ten (10) sections. Each section is discussed in more detail below to provide an overview of the report.

- **Section 1:** This section provides a project background and provides the main aspects that are covered within the feasibility study.

- **Section 2 and 3:** These sections focus on Nile and Mozambique tilapia by providing a species background and highlighting key biological and physical characteristics for each of the species. The geographical distribution of Nile and Mozambique tilapia in South Africa is also highlighted.

- **Section 4:** A detailed explanation of the potential production systems that can be used for Tilapia in South Africa is provided. These production systems are considered in the generic economic model to determine the financial viability of each system.

- **Section 5:** This section provides a detailed global, regional, and local market analysis for Tilapia. Marketing, pricing, demand and supply, and the barriers to entry are key factors to be considered before implementing an aquaculture operation.

- **Section 6:** A SWOT analysis shows a high-level overview of the Tilapia industry in South Africa. Mitigation measures are discussed to address key weaknesses and threats identified.

- **Section 7:** A technical assessment provides a brief overview of key production assumptions and guidelines that can be used for Tilapia production. These assumptions were used in the development of the generic economic model.

- **Section 8:** This section provides a financial analysis for the potential production systems based on the results obtained from the generic economic model. A high-level cost-benefit analysis is discussed to compare the feasibility of the potential production systems.

- **Section 9:** A best-case scenario is provided to highlight the minimum viable tonnage, recommended selling price and investment potential offered by the potential production systems in the nine provinces.

- **Section 10:** The last section provides the conclusion on the feasibility study and provides recommendations for the growth and development of the Tilapia industry in South Africa.

2. Nile Tilapia

2.1. Species background

The Nile tilapia (*Oreochromis niloticus*) is a benthopelagic fish (i.e. living and feeding near the bottom as well as in midwaters or near the surface) adapted to fresh water and low salinity brackish water conditions. The Nile tilapia can be distinguished from other Oreochromis species of Tilapia through the colour patterns on its body and fins. For example, the fish can be distinguished through the strong vertical bands which it has on the caudal fin, or by the grey or pink pigmentation in the throat region of the mature male. Nile tilapia is naturally distributed in Africa and coastal rivers of Israel. Produced worldwide and marketed both fresh and frozen, Nile tilapia is the most widely farmed Tilapia species in the world, representing approximately 83% of total Tilapia production (FAO, 2005 - 2017). This is because of its rapid growth, late age of sexual maturity and planktivorous feeding habits. The characteristic rapid growth to market size of Nile tilapia has made it a well-accepted fish with Tilapia farmers. The Nile tilapia is a more dependable spawner and produces more consistent quantities of fry. Survival of eggs, fry and juveniles is higher for Nile tilapia and they are more tolerant of low water temperatures than most strains of red Tilapia.

Nile tilapia generally have several attributes which make them attractive as a culture species. These include:

- High tolerance of poor water quality and crowding,
- Good performance on formulated feeds with lower protein levels,
- Acceptance of feed with a higher percentage of plant proteins,
- A relatively high degree of disease resistance,
- Widespread consumer appeal, being a mild flavoured white flesh,
- Hardiness and adaptability to a wide range of culture systems, and
- It is considered as the only economically viable Tilapia species globally (Kentucky State University Aquaculture, 2015).

Owing to its hardy nature, it has been widely introduced not only locally but globally for aquaculture, but also to augment capture fisheries, and for sport fishing. Nile tilapia is regarded as the best growing fish species by the global aquaculture community and it has been the focus of many research and development over the past two decades. Nile tilapia can live longer than 10 years and reach weights exceeding five (5) kilograms.

Nile tilapia exhibits a broad invasive potential over most of southern Africa that overlaps with the natural distribution range of the indigenous species such as Mozambique tilapia (*Oreochromis Mozambique).* Hence, the introduction of the invasive Nile tilapia into the South African river systems that are still free of Nile tilapia, is a cause of concern. It is evident that Nile tilapia has established itself and naturalised in many tropical and sub-tropical environments in eastern and southern Africa. The introduction and spreading of Nile tilapia has been identified as a problem in Limpopo and Mpumalanga (Incomati River), and is thought to pose a risk to naturally occurring Mozambique tilapia populations, as well as posing a risk to the natural biodiversity and eco-systems (Invasive Species South Africa, 2018).

Interbreeding is a major concern, and according to DAFF (2012), hybridising could lead to the loss of genetic material and adaptative value offered by the Mozambique tilapia. This includes characteristics of the Mozambique tilapia such as tolerance of low temperatures, high tolerance for salinity and drought resistance which differentiate it from the Nile tilapia (DAFF, 2017).

2.2. Statutory Classification of Nile Tilapia

As previously mentioned, Nile tilapia is listed as an Alien Invasive Species (AIS) in South Africa. According to the BRBA (2017), in accordance with Notice 3, List 7 (National List of Invasive Fresh-water Fish Species) in the AIS list (Government Notice R 864 of July 2016), Nile tilapia is categorised as follows

- **Category 1b (compulsory control)** in National parks, provincial reserves mountain catchment areas, and forestry reserves specified in terms of the Protected Areas Act.
- **Category 2 (compulsory permitting)** for aquaculture facilities in the rest of the country, and
- **Category 3 (exemptions apply)** in all other discrete catchment systems where Nile tilapia occurs.

As a Category 2 AIS, this impacts on the importation, propagation and grow-out of Nile tilapia for aquaculture operations in South Africa (DAFF, 2017).

2.3. Biological characteristics of the Nile Tilapia

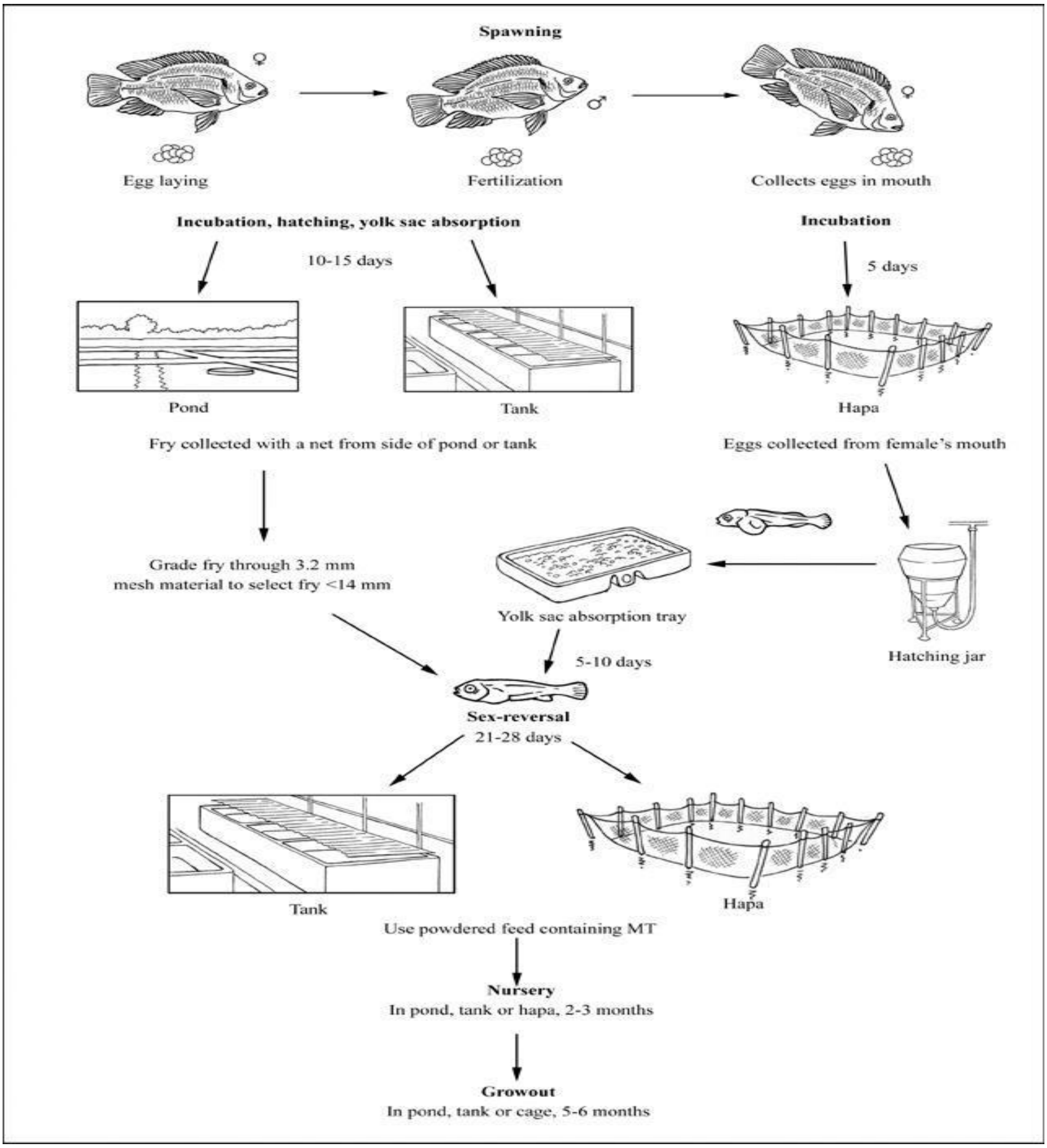
Nile tilapia can be produced in different aquaculture systems, ranging from open ponds fertilized with manure, to closed recirculating aquaculture systems (RAS). Production, varying from subsistence culture to high-tech aquaponics occurs in freshwater and in brackish water, at optimal temperatures between 28°C and 36°C, (Teichert-Coddington et al., 1997; FAO, 2012). In South Africa, certain regions with cooler climatic conditions (i.e.: Gauteng and Free State) require the use of closed-tunnel systems to provide adequate warmth for this tropical species, while areas such as Limpopo and Northern Kwa-Zulu Natal provide suitable production conditions for the majority of the year.

Under good growth conditions, the Nile tilapia will reach sexual maturity in farm ponds at an average of three (3) to five (5) months and reach a weight of 150 to 200 grams. As the fish become sexually mature (at a small size), they begin to reproduce instead of growing, leading to overcrowding and stunted growth. This forms one of the biggest drawback to the culture of Nile tilapia, as overcrowding typically results in long grow-out periods of up to a year and a small harvest yield. Overcrowding also leads to having mixed-sized fish with very little market value. It may be necessary to separate the tilapia by sex before they are old enough to reproduce, or feed male hormones to hatchlings for 21 days, to produce predominantly male fish, as a sex reversal rate of 90% can be achieved. The benefit of producing all-male fish is huge, as the culture period is reduced to as little as 6 months, and the harvest consists of even-sized, large fish with high market value. Grading of the fish is an important activity to consider, as the mono-cultured males will have a wide variety of sizes, thus grading will ensure the slow-growing fish are removed. Another simple but not very efficient way of controlling unwanted spawning is to introduce a few catfish into the pond, to eat the small fish.

Commercial tilapia production generally requires the use of male mono-sex populations. Male tilapia grow approximately twice as fast as females. Therefore, mixed-sex populations develop a large size disparity among harvested fish, which affects marketability. Moreover, the presence of female tilapia leads to uncontrolled reproduction, excessive recruitment of fingerlings, competition for food, and stunting of the original stock (FAO, 2005 - 2017) . In mixed-sexed populations, the weight of recruits may constitute up to 70 % of the total harvest weight. It is therefore necessary to reverse the sex of female fry. It is possible to create mono-sex tilapia as the fish become sexually differentiated for several days after yolk sac absorption. If female tilapia receive a male sex hormone (methyltestosterone) in their feed, they will develop as phenotypic males. Fry collected from breeding facilities need to be graded through 3.2 mm mesh material to remove fish that are >14 mm, which are too old for successful sex reversal. Swim-up fry are generally <9 mm. Sex-reversed fry reach an average of 0.2 g after 3 weeks and 0.4 g after 4 weeks. The average efficacy of sex-reversal ranges from 95 to 100% depending on the intensity of management (FAO, 2005 - 2017).

The figure below describes the production cycle of Nile tilapia.

Figure 2-1: Nile Tilapia Production Cycle



Source: (FAO, 2018)

Like other *Oreochromis* species of tilapia, the breeding process in the Nile tilapia starts when the male establishes a territory, excavates a crater-like spawning nest and guards his territory. The male mates with the females in the spawning nest. After a short mating ritual, the female spawns in the nest, and soon after fertilization by the male, collects the eggs into her mouth (buccal cavity) and moves off. The female incubates the eggs in her mouth and broods the fry after hatching, until the yolk sac is absorbed. The Incubating and brooding phase is accomplished in one (1) to two (2) weeks, depending on temperature. After the fry have been released and begin to feed, they may swim back into the mouth of the female, if danger threatens. Also, being a maternal mouth brooder, the number of eggs per spawn in Nile tilapia is small in comparison with most other pond fishes. Egg number is proportional to the body weight of the female. For example, a 100-gram female will produce about 100 eggs per spawn, while a female weighing between 600 to 1000 gram can produce between 1000 to 1500 eggs. The male remains in his territory, guarding the nest, and can fertilise eggs from a succession of females. If there is no cold period, during which spawning is suppressed, the female may spawn continuously. It is interesting to note that the female eats little or nothing during the brooding period. This explains why the female tilapia grow slower than males.

Under monoculture conditions, fry (about 1 gram in size) are stocked into nursery ponds and once they reach 30 grams, they are stocked into grow-out ponds. The stocking density under an extensive culture, where fish depend on the natural food present in the pond, is usually at 1 to 2 fingerlings per m^2 (10,000 – 20,000 fish/ha). Under the semi-intensive culture, where the fish are given supplementary feeds in addition to having the natural food present in the pond, the stocking density is 3–8 fingerlings/m^2 (30,000–80,000 fish/ha). Also, in an intensive culture system, where fish are provided and fed with only formulated feed, the stocking density of more than 8 fish/m^2 is usually used. Aquaculture systems (such as ponds) used for Nile tilapia production are usually fertilized, to maintain high levels of plankton. Hence, with artificial diet and supplemental feeding, the production of Nile tilapia improves, and harvesting can commence after six months. Under optimal growth conditions, a harvest yield of between 1500 and 4000 kg of fish can be obtained per hectare per year when producing tilapia (at a rate of 750-2000 kg per harvest). The percentage of the total marketable fish weight should be around 70%, with the remaining 30% made up of fry and fingerlings during harvesting. These smaller fish can be kept back from harvest and added to the pond during the next production cycle. Stocking density and the tonnage of fish produced plays a big role in determining the infrastructure requirements, as well as the profitability of an operation. The figures discussed were compared with industry standards for South Africa and included as variable assumptions within the generic economic model that can be altered to suit individual producer needs.

2.4. Physical requirements of Nile Tilapia

Feeding, water quality and quantity, stocking density vary throughout the lifecycle of the Nile tilapia, each one having its own financial implications, and ultimately impacting on the overall feasibility of the fish, specifically when considering the productions costs. The physical requirements of the fish impact on the type of culture systems that can be used, and the geographical and climatic conditions which are suitable for Tilapia production. The physical requirements, specifically feed, water quality and temperature factors are some of the key production assumptions used in the generic economic model, and impact on the infrastructure requirements and operational expenditure of a production system.

2.4.1. Feeding

The Nile tilapia ingest a wide variety of natural food organisms, including plankton, some aquatic macrophytes, planktonic and benthic aquatic invertebrates, larval fish, detritus, and decomposing organic matter. With heavy supplemental feeding, natural food organisms typically account for 30 to 50 % of growth. Nile tilapia are often considered as filter feeders because they can efficiently harvest plankton from the water. However, they do not physically filter the water through gill rakers as efficiently as true filter feeders such as the gizzard shad (*Dorosoma cepedianum*) and silver carp (*Hypophthalmichthys molitrix*). The gills of the Nile tilapia secrete a mucous that traps plankton. The plankton-rich mucous, or bolus, is then swallowed. Digestion and assimilation of plant material occurs along the length of the intestine (usually at least six times the total length of the fish). The

Nile tilapia is more efficient at harvesting planktonic algae when compared to the Mozambique tilapia (Popma & Masser, 1999). Nile tilapia have been known to convert natural food sources very effectively, which in some cases has resulted in more than 3000 kg of fish per hectare being sustained in well-fertilized ponds without supplemental feed being required (Popma & Masser, 1999). The nutritional value of the natural food supply in ponds is important, even for commercial operations that feed fish intensively. In heavily fed ponds with little or no water exchange, natural food organisms may provide one-third or more of total nutrients for growth.

Protein is required for optimal growth and quality of tilapia and has been reported to be as high as 50% in the diet for small fingerlings (Popma & Masser, 1999). However, in commercial food fish ponds, the crude protein content of feed is usually 26 to 30%, one tenth or less of which is of animal origin. The protein content and proportion of animal protein may be slightly higher in recirculating and flow-through systems due to the exchange or cleaning of the water source. The digestible energy requirements for economically optimum growth for tilapia in general is estimated to be 8.2 to 9.4 kcal DE (digestible energy) per gram of dietary protein. Tilapia may have a dietary requirement for fatty acids of the linoleic (n-6) family. The feeding behaviour of tilapia allows them to use a mash (unpelletized feeds) but most commercial tilapia feeds are pelletized to reduce nutrient loss.

Commercial fish feed for tilapia aims to meet the nutritional requirements of the fish to ensure maximum, healthy growth of the fish. Throughout the fish life cycle, the feed requirements in terms of volume, type of feed, and feed conversion ratio (FCR) will change. Table 2-1 below provides an overview of South African feed producers AVI products who have developed feed specifically to meet the needs of tilapia. The feed requirements below is for Nile tilapia being cultured at 27°C, which is important to note as feed requirements and rates differ according to temperature.

Table 2-1: Commercial feed requirements for Nile tilapia

Life Stage	Week	Start Weight (gram)	End Weight (gram)	Growth Rate/Life Stage	FCR
Fry Powder (No. 0) 45%	1 - 3	0,02	0,42	0,40	0,90
Fry Crumb (No. 1) 45%	4 - 6	1,13	4,79	3,66	0,95
Starter Crumb (No.2) 40%	7 - 8	8,33	13,44	5,11	1,00
Starter Crumb (No.3) 40%	9 - 10	20,44	29,67	9,23	1,00
Juvenile (Starter 2 mm) 40%	11 - 12	41,48	56,21	14,73	1,00
Grower (3 mm) 35%	13 - 21	74,21	378,31	304,10	1,20-1,30
Finisher (5 mm) 30%	22 - 30	441,66	1223,67	782,02	1,35-1,40

Adapted from (Avi Products, 2018)

As seen in the table above, each life stage requires a unique feed type, ranging from fry powder and crumb, to starter crumb, and pellets for juvenile, grower, and finisher stages of the lifecycle. Each feed type has specific nutritional output that will provide the adequate nutrients and protein required by the fish. The average feed price indicated by local producers is approximately R12/kg, however AVI feed prices range from R16 to R18/kg depending on the type of feed required. Feed is an essential aspect of production as it is one of the highest production costs for producers and plays a major role in the quality and growth of the fish.

2.4.2. Salinity

All tilapia are tolerant to brackish (slightly salty) water. The Nile tilapia is the least saline tolerant of the commercially important species but grows well at salinities up to 15 ppt[1]. The Nile tilapia reproduces at salinity levels of 10 to 15 ppt but perform better at salinities below 5 ppt. Fry numbers decline substantially at 10 ppt salinity (Popma & Masser, 1999).

2.4.3. Water temperature

Generally, a tilapia stops feeding when water temperature falls below 17°C. The intolerance of tilapia to low temperatures is a serious constraint for commercial culture in temperate regions. The lower and upper lethal temperatures (i.e. the survival limit) for Nile tilapia are 11-12 °C and 42 °C, respectively, while the preferred temperature ranges from 28°C to 36 °C (FAO, 2005 - 2017). Growth at this optimal temperature is typically three times greater than when the temperature is lower. Reproduction is best at water temperatures higher than 27°C and does not occur below 20°C (Popma & Masser, 1999). In subtropical regions with a cool season, the number of fry produced will decrease when daily water temperature averages is less than 24°C.

2.4.4. Oxygen Requirement

Tilapia generally survive routine dawn dissolved oxygen (DO) concentrations of less than 0.3 mg/L, considerably below the tolerance limits for most other cultured fish. Studies show that Nile tilapia grow better when aerators are used to prevent morning DO concentrations from falling below 0.7 to 0.8 mg/L (compared with unaerated control ponds) (Popma & Masser, 1999). Although tilapia can survive acute low DO concentrations for several hours, tilapia culture systems should be managed to maintain DO concentrations above 1 mg/L. Metabolism, growth and, possibly, disease resistance are depressed when DO falls below this level for prolonged periods.

2.4.5. pH Requirement

In general, tilapia can survive in pH of water supply ranging from 5 to 10 but perform optimally in a pH range of 6 to 9. Acidic water (below pH 5) will require the use of a reservoir where water acidity is neutralizing using lime before use. The pH level of supply water can be measured with a pH test kit or pH meter.

2.4.6. Water Requirement

A typical pond culture grow-out for tilapia, that discharges all effluent, will require approximately 3 250 to 3 750 m^3 of water per hectare per month. Recirculating pond systems (zero discharge) may use as little as 300 m^3 of water per hectare per month and water supply will be required to top up the water levels based on the evaporation rates experienced at the tilapia farm, however, this is very area or climatic region specific. Some regions in South Africa such as the Northern Cape experience high evaporation rates due to air temperatures and weather conditions, while other provinces experience lower evaporation rates. Most often this water will have to be pumped into the farm, but any site that has sufficient elevation to allow water to feed the farm by gravity will save much on energy costs. Ground water can be used, but it requires more expensive capital investment and pumping costs. One major advantage of using ground water is that it offers a reduced risk of containing predators, additional aquatic life and most importantly, disease organisms.

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[1] *Parts per thousand*

2.4.7. Ammonia Requirement

Ammonia is very toxic to tilapia, and they are not able to survive in water with unionised ammonia concentration of less than 2mg/L. When Tilapia are transferred into water that do not meet the above stated ammonia requirement, massive mortality usually occurs within a few days. However, when gradually adapted to sub-lethal levels, approximately half the fish will survive 3 or 4 days at unionized ammonia concentrations as high as 3 mg/L. The first mortalities from prolonged exposure may begin at concentrations as low as 0.1 mg/L. Unionized ammonia begins to reduce food consumption at concentrations as low as 0.08 mg/L. From the information above, it is recommended that ammonia levels be maintained below 0.1 mg/L (El-Sayed, 2006).

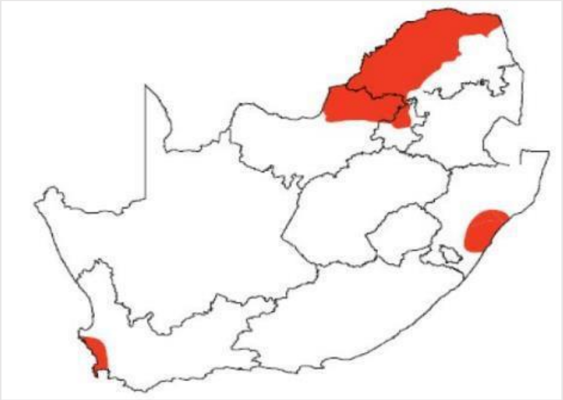
2.5. Geographical distribution of Nile Tilapia in South Africa

As the climate and geographic conditions differ across South Africa, it is important to understand the suitability of the nine provinces for tilapia production, specifically regarding the climatic and geographic distribution, which has a major impact on the temperature. Temperature is a key influencing factor for aquaculture as it determines and impacts on the type of production systems that can be used, as well as the financial implications related to the costs and infrastructure required to heat the water. Temperature variations and evaporation rates were considered in the generic economic model to ensure that electricity, water, and infrastructure costs account for the temperature variations found in the different provinces.

2.5.1. Distribution of the Nile Tilapia

According to the Biodiversity Risk and Benefit Assessment (BRBA) on Nile tilapia, this species has been introduced across the country since the 1950's. While not all introductions were successful, Nile tilapia can now be found in several river systems around South Africa and pose a threat to not only Mozambique tilapia, but other tilapia species due to the risk of hybridisation. Wild populations of Nile tilapia have been identified in the Incomati and Limpopo rivers which is mainly attributed to the suitable temperature ranges found in these regions. Other wild populations have been identified in South Africa, however these seem to be seasonal as the cold winter months in South Africa do not provide suitable growing or breeding conditions for the Nile tilapia (DAFF, 2017).

Figure 2-2: Introduced Nile tilapia populations



2.5.2. Suitability Assessment

The main factor considered in determining the areas suitable to culture Nile tilapia in South Africa, is the optimal temperature under which they survive. Although other factors such as water quality, soil quality, topography, infrastructure, etc., are also important but should be considered more closely at a site-specific level. The tolerable water temperature range for Nile tilapia is 11 – 42°C, while the optimal temperatures under which they thrive ranges from 28°C to 36°C. This restricts maximum growth to only a few months during summer (i.e. from November to February in South Africa). As such, the most thermally efficient areas to culture tilapia would be the areas that experience warm summers and mild winters. Low winter temperatures experienced in the majority of South Africa will result in either unsuitable conditions for year-round tilapia culturing, or slower growth rates during cooler months. Heating and temperature regulating infrastructure like tunnels and heating pumps are required to ensure year-round production is achieved, however, this has major impacts on operational expenses and infrastructure costs.

According to the BRBA, twelve eco-regions[2] in South Africa were identified as suitable regions for Nile Tilapia to survive naturally. Established Nile tilapia populations have been recorded in eight (8) eco-regions. Based on the eco-regions identified in the map below, the following provinces are considered to be suitable for Nile tilapia production in South Africa:

- ✓ Limpopo
- ✓ Northern Kwa-Zulu Natal
- ✓ Mpumalanga
- ✓ Selected regions of Western Cape
- ✓ Selected regions of the Northern Cape
- ✓ Select regions of the North West Province

Currently, the majority of registered[3] Tilapia farms are located in the Gauteng, Limpopo, Mpumalanga, and the North West provinces respectively, however this is for both Nile and Mozambique tilapia production (DAFF, 2016). Most tilapia farmers are small scale farmers and they employ the RAS and pond culture systems. The Limpopo province accounts for the highest share (37%) of South Africa's tilapia production, this is followed by the North West (26%) and the Gauteng Province (18%), respectively. The Eastern Cape, KwaZulu Natal, Mpumalanga, Northern Cape and Western Cape collectively accounted for 19% of the total tilapia production (DAFF, 2016).

While the eco-regions below identify suitable regions for Nile Tilapia to exist naturally, it is important to note that some regions may only be suitable in summer, thus Nile tilapia populations may be found seasonally in some regions. It is important to note that aquaculture operations (both existing and new projects) would generally be based on indoor systems where water temperature is regulated, thus, Nile tilapia farming can be successfully conducted in regions outside of the environmental range identified.

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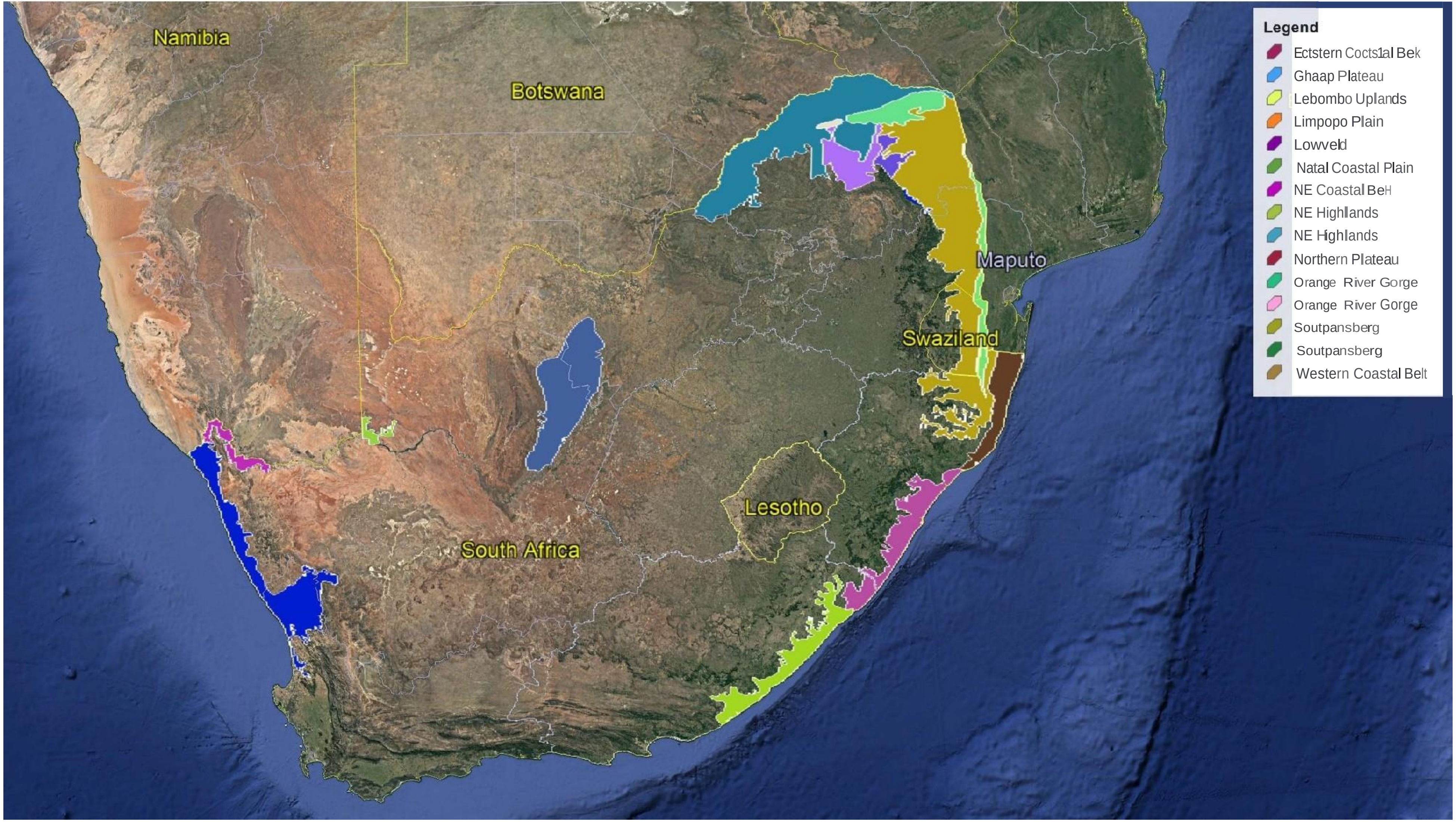
[2] *Regions are based on air temperature and identify suitable areas for Nile tilapia to survive naturally.*

[3] *This only accounts for Tilapia farms that are registered and provide records to DAFF*

Figure 2-3: Suitable Eco-regions for Nile Tilapia



(Urban-Econ, 2018)

2.5.3. Key Location and Site Requirements

There are many factors that can influence the success of an aquaculture enterprise. Site selection is one of the most important factors and often does not get adequate attention. Important factors that have to be considered in selecting a specific site for Nile tilapia production are:

I. Climate (water and environmental temperature),
II. Slope and topography (avoid flood prone areas),
III. Soil type (applicable to open culture systems),
IV. Quantity and quality of water must be analysed (pH, alkalinity, ammonia, nitrite, etc.), and
V. Proximity to market (market research, demand, price, distance to processing plant, etc.).

2.5.4. Key requirements for profitability

When considering the profitability of Nile tilapia, in addition to the financial results obtained from the generic economic model, the following factors could impact on the profitability of Nile tilapia:

I. Hatchery: access to hatchery or good quality fingerlings,
II. mono sex fry,
III. Appropriate water temperature,
IV. Appropriate water quality and quantity,
V. Suitable site with right soil type, slope, and topography;
VI. Economies of scale and consistent volume of production,
VII. Good access to production inputs and support services,
VIII. Good farm management practices,
IX. Access to market, and
X. Disease control and management.

3. Mozambique Tilapia

3.1. Species background

The Mozambique tilapia (*Oreochromis mossambicus*) is a deep bodied fish native to the eastward-flowing rivers of central and southern Africa aquaculture systems. This species of tilapia has its evolutionary origin in the Zambesi River Basin and has since spread southwards, through most of the warmer regions Southern Africa. Since the Mozambique tilapia is indigenous to Southern Africa, it constitutes one of the most preferred species for aquaculture production in the region. The Mozambique tilapia is found in many different waters, except for fast-flowing rivers and streams. They are known to prefer slow moving water bodies such as lagoons, rivers, and impoundments.

The Mozambique tilapia is considered a freshwater species (Froese & Pauly, 2017) but it can be found in both estuaries and coastal lakes. They are often the most abundant species in disturbed habitats like urban drainages, as they can tolerate a wide range of conditions. The Mozambique tilapia has several positive qualities, which makes it a good candidate species for aquaculture. These include:

I. High fecundity (females produce about 500 eggs every second week),
II. Very tolerant of high salinities,
III. Adaptable to extreme environment conditions,
IV. Ability to utilise plant and animal nutrients for growth,
V. High meat quality, with good market acceptance,
VI. Indigenous to South Africa, and
VII. Potential to develop value-added fish products.

Despite the positive qualities of the Mozambique tilapia as an aquaculture species, it should be noted that it is a slow growing species, specifically when compared to the Nile tilapia which experiences an estimated 40% faster growth rate in comparison to the Mozambique tilapia. This could be a major limitation for culturing the Mozambique tilapia at a commercial level, as it may not be economically viable, which is supported by the results obtained from the generic economic model. Through genetic research, and breeding programmes, efforts are underway to increase the growth rates of Mozambique tilapia, which may make it more commercially viable and profitable if this can be achieved (ABARES, 2012).

3.2. Biological characteristics of Mozambique Tilapia

Mozambique tilapia have a dull greenish or yellowish coloration, although, this colour intensity can be influenced by differing environmental conditions, state of sexual maturity, body size and food source. Hence, it is often an unreliable method of distinguishing this tilapia species. Generally, both male and female Mozambique tilapia have a long, continuous dorsal (upper) fin that starts from above the gills and continues along most of the upper body. The dorsal and anal fins are elongated towards the end of the fish and easily reach to the tail fin, when depressed against the body. The tail fin is rounded and often has a red margin in adult fish (ABARES, 2012).

Sexually mature males differ from females in several ways. They have a slightly concave forehead, with a protruding jaw and thickened lips. Males can also display breeding colouration where the top two-thirds of their body will be dark grey or deep purple-black, and the lower third is a light cream or a light grey colour, especially the lower cheeks and jaws. Sexually mature females and immature males display the same light cream or light grey underbelly colour, which blends to a darker grey or silvery-olive colour on the upper half of the body. Juvenile and sub-adult fish are usually a much lighter, silvery-grey colour. Females and sexually immature males can have up to five dark coloured, circular blotches along the mid-section of their body. Fish that are less than 10 cm in size often have dark vertical stripes along the sides of the body with a dark black spot present at the base of the dorsal fin. This spot is sometimes also ringed by a lighter grey margin and is often referred to as the 'tilapia spot (ABARES, 2012).

The Mozambique tilapia can live for up to ten (10) years and reach a length of over 40 cm under optimal conditions, with males typically growing larger than females. However, where environmental conditions are poor, such as in disturbed habitats, the growth of the Mozambique tilapia can become stunted and mature at much smaller sizes. Although sexual maturity in tilapia is a function of age, size and environmental conditions, the Mozambique tilapia reaches sexual maturity at a smaller size and younger age than the Nile and Blue tilapia. Mozambique tilapia may reach sexual maturity in as little as three (3) months of age, when they seldom weigh more than 60 to 100 grams (Popma & Masser, 1999). Mozambique tilapia are polygynous (i.e. males' mate with multiple females), sexually dimorphic, and maternal mouthbrooders. They can reproduce under a variety of different ecological conditions. Due to their ability to stunt their own growth, Mozambique tilapia can also vary greatly between populations in their reproductive characteristics. Mozambique tilapia are prolific spawner, having the ability to spawn and rear multiple broods during a season. During the breeding season, mature males congregate in shallow margins of waterbodies and establish courtship arenas. Each male digs a shallow circular pit which is aggressively defended and used for display to attract a receptive female. Generally, the largest male will win territorial contests, and this is advertised to females and other males through sounds and urinary odours (Barata, et al., 2008).

Once a female has chosen a male, she will swim over his pit (nest) where courtship and spawning take place. Females lay their eggs into the males' nest. The male then immediately releases milt (sperm) over the pit, which the female gulps at to fertilise her eggs. After fertilisation of eggs within the pit, the female collects the eggs in her mouth and establishes a brooding territory elsewhere. The female broods the embryos in her mouth for a period of 20 - 22 days. Females aggressively defend eggs and fry from predators during this time. Once the fry can swim freely, they will leave the female for brief periods but return to her mouth if threatened. Temperature regulates reproduction patterns, with spawning thresholds for the species reported between 18°C and 25°C (Webb & Maughan, 2007). Spawning is virtually continuous in regions where temperature remains above at least 24°C year-round. Brood size is related to female body size and can range between a few hundred for stunted (early maturing) females to between 2000 and 4000 eggs for large females. Even though the frequency at which spawning occurs is strongly influenced by temperature, the Mozambique tilapia is a multiple spawner and can produce several broods during a season. For example, in South Africa, females have been seen spawning up to five times over a four-month period (James & Bruton, 1992). As a result, survivorship of eggs and fry can be very high, with rates (under laboratory conditions) reported of between 50 and 95%, thus allowing for very rapid population increase under favourable conditions (Webb & Maughan, 2007).

The figure below illustrates the production cycle of Mozambique tilapia.

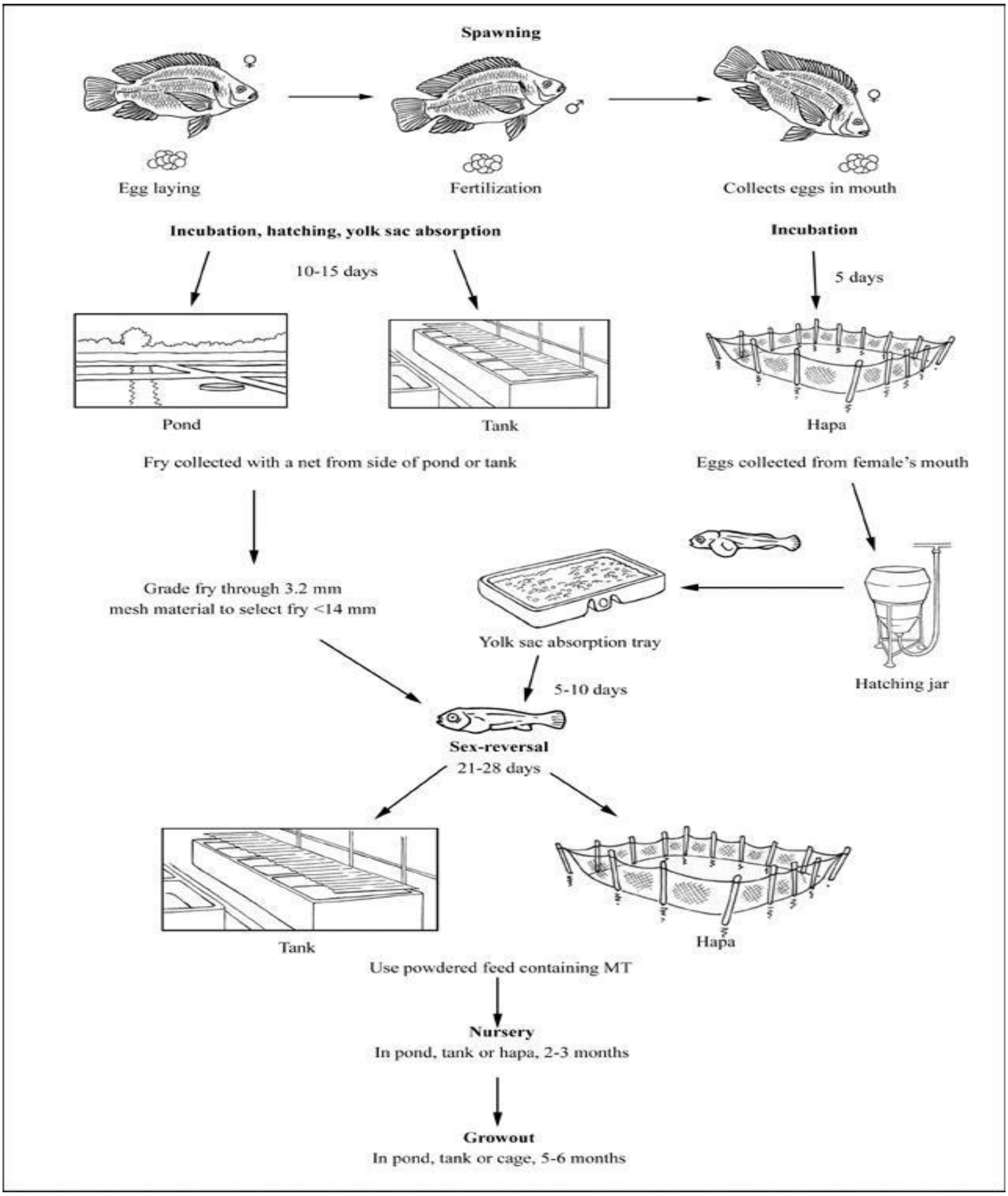


Figure 3-1: Production Cycle of Mozambique Tilapia

(FAO, 2005 - 2017).

3.3. Physical requirements of the Mozambique Tilapia

Feeding, water quality and quantity, stocking density vary throughout the lifecycle of the Mozambique tilapia, each one having its own financial implications, and ultimately impacting on the overall feasibility of the fish, specifically when considering the productions costs. The physical requirements of the fish impact on the type of culture systems that can be used, and the geographical and climatic conditions which are suitable for tilapia production. The physical requirements, specifically feed, water quality and temperature factors are some of the key production assumptions used in the generic economic model, and impact on the infrastructure requirements and operational expenditure of a production system.

3.3.1. Feeding

Mozambique tilapia are opportunistic omnivores and will eat algae (although they are less efficient at harvesting planktonic algae than the Nile tilapia), plant matter, decomposing organic particles, insect larvae, small aquatic invertebrates, and fish. The Mozambique tilapia will adapt its diet to the environment and as such, the exact diet of this species varies a lot from location to location. Such a broad diet range also enables the Mozambique tilapia to colonise different environments, since they do not rely on a particular food source. In situations where the fish are concentrated in one spot, adults sometimes cannibalise younger fish.

In captivity and in commercial aquaculture systems, tilapia are exposed to both algae and pelleted foods, and the fish may learn to feed itself using demand feeders. During feeding in commercial systems, the fish jump out of the water in a vigorous manner (Froese & Pauly, 2017). Feeding is normally uninterrupted, however, during the brooding period, the females cease to feed and subsist on food reserves stored in their body (Froese & Pauly, 2017).Generally, tilapia use natural food so efficiently that crops of more than 3000 kg of fish per hectare can be sustained in well-fertilized ponds without supplement feed (Popma & Masser, 1999). The nutritional value of the natural food supply in culture systems (e.g. ponds) is important, even for commercial operations that feed fish intensively. In heavily fed culture systems, with little or no water exchange, natural food organisms may provide one-third or more of total nutrients for growth. Like other strains of tilapia, the Mozambique tilapia digest animal protein in feeds, with an efficiency similar to that of the channel catfish but are more efficient in the digestion of plant protein, especially more fibrous materials.

Commercial fish feed for tilapia aims to meet the nutritional requirements of the fish to ensure maximum, healthy growth of the fish. Throughout the fish life cycle, the feed requirements in terms of volume, type of feed, and feed conversion ratio (FCR) will change. Throughout the fish life cycle, the feed requirements in terms of volume, type of feed, and feed conversion ratio (FCR) will change. Table 3-1 below provides an overview of South African feed producers AVI products who have developed feed specifically to meet the needs of tilapia.

Table 3-1: Feed requirements for Mozambique Tilapia

Life Stage	Week	Start Weight (gram)	End Weight (gram)	Growth Rate/Life Stage	FCR
Fry Powder (No. 0) 45%	1 - 3	0,02	0,42	0,40	0,90
Fry Crumb (No. 1) 45%	4 - 6	1,13	4,79	3,66	0,95
Starter Crumb (No.2) 40%	7 - 8	8,33	13,44	5,11	1,00
Starter Crumb (No.3) 40%	9 - 10	20,44	29,67	9,23	1,00

Juvenile (Starter 2 mm) 40%	11 - 12	41,48	56,21	14,73	1,00
Grower (3 mm) 35%	13 - 21	74,21	378,31	304,10	1,20-1,30
Finisher (5 mm) 30%	22 - 30	441,66	1223,67	782,02	1,35-1,40

Adapted from (Avi Products, 2018)

As seen in the table above, each life stage requires a unique feed type, ranging from fry powder and crumb, to starter crumb, and pellets for juvenile, grower, and finisher stages of the lifecycle. Each feed type has specific nutritional output that will provide the adequate nutrients and protein required by the fish. The average feed price indicated by producers is around R12/kg, however prices from AVI products range from R16 to R18/kg depending on the type of feed required. Feed is an essential aspect of production as it is one of the highest production costs for producers and plays a major role in the quality and growth of the fish.

3.3.2. Salinity

Mozambique tilapia is reportedly one of the most salinity tolerant tilapia species. According to reports, Mozambqiue tilapia can tolerate up to 120 % salinity, and can grow and reproduce normally at water salinity of between 10 and 49 %. Mozambique fry can live and grow reasonably well at salinities of up to 69 %. Furthermore, their reproduction efficiency is better in brackish water than in fresh water. Uchida and King (1962) found that seed production of *O. mossambicus* was approximately three times higher in brackish water (8.9–15.2%) than in fresh water (El-Sayed, 2006).

3.3.3. Water temperature

The optimal temperature range required by Mozambique tilapia for growth and reproduction is between 28 - 30°C (FAO, 2010; Shipton & Britz, 2007). The species can, however, survive at temperatures between 16 and 39°C (ABARES, 2012). Survival at low temperatures, however, can be increased where water have a higher salt content than pure freshwater. In South Africa, Mozambique tilapia have been found to survive temperatures as low as 11°C in brackish waters.

3.3.4. Oxygen Requirement

The Mozambique tilapia is a facultative air-breather and, depending on air temperature, can survive complete air exposure for several hours. Mozambique tilapia can tolerate low dissolved oxygen concentrations of 0.1 ppm (0.1 mg/L)[4] for short periods, (Webb & Maughan, 2007). However, culture systems (e.g. ponds) should be managed to maintain dissolved oxygen concentrations above 1 mg/L. Metabolism, growth and possibly, disease resistance are depressed when dissolved oxygen falls below this level for prolonged periods (Popma & Masser, 1999).

3.3.5. pH Requirement

In general, Mozambique tilapia can survive in pH ranging from 5 to 10, however optimal production occurs at a pH range of 6 to 9, (Popma & Masser, 1999). The Mozambique tilapia can tolerate extremes of acidity and alkalinity, with pH values ranging between 3.7 and 10 (van Ginneken et al. 1997; Leghari et al. 2004). The alkaline and acidic lethal limit of pH for Mozambique tilapia is 11 and 3.4 respectively (Webb & Maughan, 2007).

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[4] Parts per million

3.3.6. Water Requirement

A typical tilapia grow-out farm, which discharges all effluent, will require approximately 3 250 to 3 750 m³ of water per hectare per month. Recirculating pond systems (zero discharge) may use as little as 300 m³ of water per hectare per month and water supply will only be needed during the dry season. Ideally, a site should have year-round water supply. Most often this water will have to be pumped into the farm, but any site that has sufficient elevation to allow water to feed the farm by gravity will save much on energy costs. Ground water can be used, but it requires more expensive capital investment and pumping costs. One major advantage of using ground water is that it is free of predators, aquatic life and most important, disease organisms.

3.3.7. Nitrogen/ Ammonia Requirement

Nitrites are highly toxic to fish, including Tilapia as it disturbs the physiological functions of the fish and can lead to growth retardation. Mozambique tilapia can tolerate levels of nitrogen concentration of 14 mg N/L. The species also tolerates ammonia stress up to 3 mg/NL without significant reduction in food intake or growth. If tilapia are placed in water that does not meet the ammonia requirements, high mortality rates can be experienced within a few days.

3.4. Geographical distribution of Mozambique Tilapia in South Africa

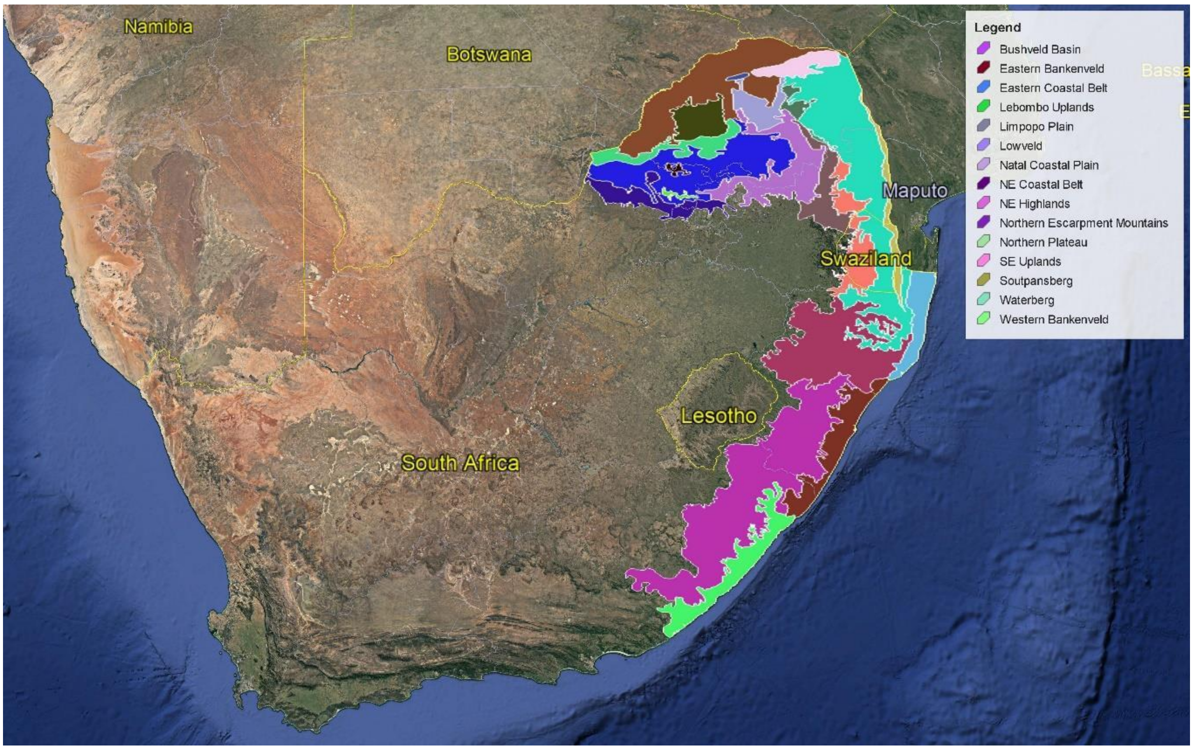
As the climate and geographic conditions differ across South Africa, it is important to understand the suitability of the nine provinces for tilapia production, specifically regarding the climatic and geographic distribution, which has a major impact on the temperature. Temperature is a key influencing factor for aquaculture as it determines and impacts on the type of production systems that can be used, as well as has financial implications on the water heating and infrastructure costs. Temperature variations and evaporation rates were considered in the generic economic model to ensure that electricity, water, and infrastructure costs account for the temperature variations found in the different provinces.

3.4.1. Suitability Assessment

Although tilapia culture is possible throughout most lowland areas of South Africa, using the various modern aquaculture technology; it is still important to determine the most thermally efficient areas to culture the species under extensive systems (e.g. ponds), with little or no technology application. As such, the main factor considered in determining the thermally efficient areas to culture Mozambique tilapia in South Africa is the optimal temperature under which they survive. Other relevant factors such as water quality, water temperature, soil quality, topography, infrastructure, type of technology, skills availability, etc., should also be considered but at a site-specific level. In terms of the optimal temperature under which the Mozambique tilapia survives, the tolerable water temperature range for the fish is between 16°C and 39°C, while the optimal temperatures under which they thrive fall between 28°C and 30°C. It should be noted that as water temperature falls below 28°C, reduced metabolic activity occurs and this results in a decline in growth rates. Reduced growth rates also result in longer grow-out periods and lower levels of farm production.

In accordance with the IUCN Red List data, Figure 3-2 below shows the range and suitable regions for Mozambique tilapia in South Africa. It should be noted this is specifically for natural/wild populations of Mozambqiue tilapia, however, it provides a good indication of the most suitable provinces. Under the sub-tropical temperature regimes that prevail in South Africa, tilapia farming is either restricted to seasonal production (during the warmer summer months), or alternatively, can be undertaken under thermally controlled conditions in highly intensive production systems that allow production throughout the cooler winter months.

Figure 3-2: IUCN Range for Mozambique Tilapia in South Africa



Adapted from IUCN Data (Urban-Econ,2018)

Based on the map shown above and considering that the most the tolerable water temperature range for Mozambique tilapia is 28°C to 30°C, which makes the following provinces suitable for Mozambique tilapia production:

- Eastern Cape (with the exception of the escarpment bordering Lesotho),
- Kwa-Zulu Natal (specifically Northern KZN and along the coast line),
- Mpumalanga,
- Northern Gauteng, and
- Limpopo.

Currently, the majority of registered Mozambique tilapia farms are located in the Gauteng, Limpopo, Mpumalanga, and the North West provinces respectively (DAFF, 2016) [5]. Most tilapia farmers are small scale farms and they employ recirculation and pond culture systems. In terms of production volumes, the Limpopo province accounts for the highest share (37%) of South Africa's tilapia production, followed by the North West (26%) and the Gauteng Province (18%) respectively. The remaining five provinces (Eastern Cape, KwaZulu Natal, Mpumalanga, Northern Cape and Western Cape) collectively account for 19% of the total Tilapia production in South Africa (DAFF, 2016).

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[5] *Data on both Nile and Mozambique tilapia are usually combined, hence, the number of farms involved in the production of only Mozambique Tilapia could not be accurately determined.*

3.4.2. Key Location and Site Requirements

There are many factors that can influence the success of an aquaculture enterprise. Site selection is one of the most important factors and often does not get adequate attention. Important factors that have to be considered in selecting a specific site for culturing Mozambique tilapia include:

I. Climate (water and environmental temperature),
II. Slope and topography (flood-prone areas should be avoided),
III. Soil type (applicable to open culture systems),
IV. Quantity and quality of water must be analysed (pH, alkalinity, ammonia, nitrite, etc.), and
V. Proximity to market (market research, demand, price, distance to processing plant, etc.).

3.4.3. Key requirements for profitability

The list below illustrates the optimal operational requirements, at a high-level, for Mozambique tilapia aquaculture to be profitable. In addition to the financial results obtained from the generic economic model, the following factors could impact on the profitability of Mozambique tilapia:

I. Hatchery or access to fingerlings,
II. Mono sex fry,
III. Appropriate water temperature,
IV. Appropriate water quality and quantity,
V. Suitable site with right soil type, slope, and topography,
VI. Economies of scale and consistent volume of production,
VII. Good access to production inputs (including feed) and support services,
VIII. Good management practices,
IX. Access to market, and
X. Disease control and management.

4. Potential Culture Systems for Nile and Mozambique Tilapia

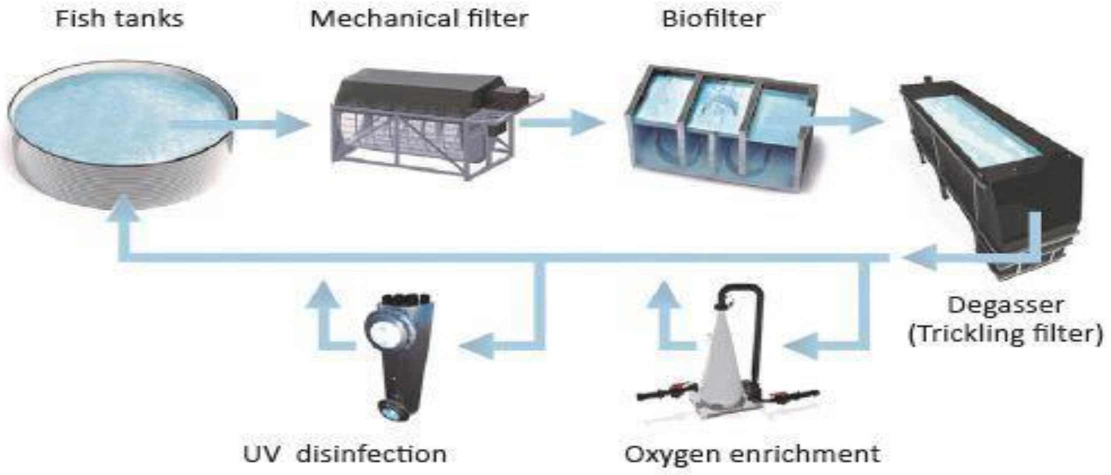
Currently, there is a lack of large-scale intensive tilapia farms operating in South Africa and the majority of the small farms use the traditional cage and pond culture aquaculture system. The industry has however, moved towards more modern farming methods, namely farming Tilapia in green houses which helps to regulate water temperatures, thereby increasing the growth rates of fish. The potential production systems identified are considered in the generic economic model to determine the financial feasibility of each system from an economic perspective. Each production system is unique in terms of the infrastructure requirements and operational costs. The potential culture systems that could be used to culture tilapia in South Africa include the following:

4.1. Recirculating Aquaculture Systems

Recirculation aquaculture systems (RAS) have been developed, mostly in the temperate regions, to culture tilapia year-round under controlled conditions. RAS makes use of technology that allows for the reuse of water in production, as the system is based on mechanical and biological filters. RAS can be used at different intensities depending on the volume of water that is being recirculated or re-used. By making use of recirculation technology, fish producers can control all the production parameters in the system, thus making skills and expertise in not only aquaculture but RAS essential (Bregnballe, 2015).

According to Bregnballe (2015), the following aspects play an important role in a RAS:

I. Fish rearing tanks,
II. Mechanical filter,
III. Biofilter,
IV. Degassing unit (trickling filter),
V. Oxygen enrichment, and
VI. UV disinfection.



Source: (Bregnballe, 2015)

A recirculating system is not limited to the six aspects mentioned above and can be tailored specifically for tilapia production and site conditions of the aquaculture operation.

The fish rearing tanks are generally circular to facilitate solids removal, although octagonal tanks and square tanks with rounded corners provide a suitable alternative with better space utilization. Drum filters are widely employed for solids removal, although other devices (bead filters, tube settlers) are often used. In oxygenated systems, a stage is provided for vigorous aeration to vent carbon dioxide into the environment. Rearing tank retention times are relatively short (e.g. one hour) to remove waste metabolites for treatment and return of high-quality water. According to the FAO (2005-2017) recirculation systems are designed to replace 5 to 10 % of the system’s volume each day, with new water. This amount of exchange prevents the build-up of nitrates and soluble organic matter that would eventually cause problems (FAO, 2005 - 2017). It should be noted that the water exchange percentage is largely dependent in the degree of biomass found in the production system, and currently in South Africa, water exchanges fall below the 5 – 10% identified by the FAO (Personal Communication, 2017). Some systems apply additional treatment processes such as ozonisation, denitrification, and foam fractionation.

International examples indicate that production levels in recirculation aquaculture systems range from 60 to 120 kg/m^3 of rearing tank volume, or more (FAO, 2005 - 2017).It should be noted that these volumes are not being achieved in South Africa, with producers stocking from 20 – 30 kg/m^3, depending on their capabilities, access to infrastructure and availability of capital. However, the final standing crop is not the best indicator of system efficiency; the maximum daily feed input to a system is a better indicator of both productivity and efficiency. Feed input and other factors that promote production are captured by the production to capacity ratio (P/C), the ratio of system output to maximum carrying capacity. For Tilapia, P/C ratios of >4.5 are possible and ratios of >3 may be necessary for profitability. Intensive stock management practices, such as multiple cohort culture with regular partial harvests and restocking, are needed to reach high P/C ratios.

Advantages of using the recirculating aquaculture systems

I. This technology improves:
    - ✓ the productivity per unit species
    - ✓ biosecurity control,

II. The system boosts freshwater aquaculture production dramatically and allows for intensive aquaculture production to be undertaken on a smaller footprint,

III. Relatively low water consumption: The system can be located in areas that do not have sufficient water resources for pond aquaculture,

IV. The system can also be located closer to markets and infrastructure, such as highway connections and utilities,

V. Indoor operations protect the fish stock from seasonal variations in temperature, allowing year-round production that satisfies constant market demand,

VI. Relatively small area is needed,

VII. The RAS system allows for easy harvesting, and

VIII. Can be set-up in almost every area, even in cold climates.

Disadvantages of using the recirculating aquaculture systems

I. Requires technical skills and expertise,

II. Optimising the RAS design for the site conditions can be challenging,
III. Large capital investment is required for building and starting up facilities,
IV. High and constant demand of power,
V. Highly technical installation,
VI. Maintenance cost is also relatively high, and
VII. Can increase production costs, which will impact of feasibility and profitability of a Tilapia production operation.

4.2. Aquaponics

The aquaponics system is suitable for culturing tilapia in regions that exhibit feasibility (in terms of market, temperature, infrastructure, etc.) for production but have less suitable resources such as water supplies, soil type or topography. The aquaponics systems combines the culture of fish and plants in closed recirculating systems. Waste nutrients from the aquaculture effluent are used to produce plant crops (Rakocy, et al., 2004).

Nutrients, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes, are absorbed by plants cultured hydroponically (i.e. a soilless system for crop production). Aquaponic systems require very little water and land for the intensive production of tilapia, hydroponic vegetables, and other crops such as culinary herbs, medicinal herbs and cut flowers. In the aquaponics system, the aquaculture effluent typically supplies most of the required plant nutrients in adequate amounts, with only little supplementation required (Rakocy, et al., 2004).

As the aquaculture effluent flows through the hydroponic component of the recirculating system, fish waste metabolites are removed by nitrification and direct uptake by the plants, thereby treating the water, which flows back to the fish-rearing component for reuse. Continuous generation of nutrients from fish waste prevents nutrient depletion while uptake of nutrients by the plants prevents nutrient accumulation, extends water use, and reduces discharge to the environment. Culture water can be used continuously for years, under the aquaponics system. The technology associated with aquaponics is fairly complex. It requires the ability to simultaneously manage the production and marketing of two different agricultural products. Aquaponic systems can be highly successful, but they require careful management, as they have special considerations. The main factors when deciding where to place an aquaponics unit are: stability of ground; access to sunlight and shading (most of the common plants for aquaponics grow well in full sun conditions, however, extreme environmental conditions can stress plants and destroy structures); exposure to wind and rain (strong and prevailing wind and rain fall can cause damages) ; availability of utilities; and availability of a greenhouse or shading structure (FAO, 2014).Essential components of the aquaponics system include the following:

I. The fish tank,
II. The mechanical and biological filter,
III. The plant growing units (media beds, nutrient film technique (NFT) pipes or deep-water

culture (DWC) canals),

IV. Water/air pumps,
V. UV disinfection, and
VI. Degassing unit (FAO, 2017).

Advantages of using the aquaponics system

I. Ease of harvest,
II. Tilapia can offer good development/growth rates when produced in an aquaponics system,
III. Aquaponics utilises the nutrient rich water from aquaculture, that otherwise would have been a waste product or would need to be filtered in a costly manner, to produce other valuable plants,
IV. Significant reduction in the usage of water. Aquaponics uses a fraction of the water that traditional field production does, because no water is wasted or consumed by weeds,
V. Significant reduction in land is required to grow the same crops as traditional soil methods. In aquaponics, plant spacing can be very intensive - allowing for the growing of more plants within a given space,
VI. Growth of plants is significantly faster than traditional methods using soil,
VII. Reduced damage to plants from pests and disease. In aquaponics, there cannot be any pesticides or herbicides used, making final product healthier and safer, and
VIII. Aquaponics offers the producer two income streams/output products if both the fish and vegetables are harvested.

Disadvantages of the Aquaponics System

I. Can be expensive to setup, as a recirculating system and plant production infrastructure is required,
II. Setup and management require technical knowledge of aquaponics systems,
III. Water needs to be constantly monitored to make sure the water quality is suitable for fish,
IV. Aquaponics requires electric energy input to maintain and recycle water within the system,
V. If one or more components fail, it could lead to the loss of fish and/or plants. As such, the system is dependent on using reliable technology (and backup systems) to prevent production losses,
VI. Fish growth can be affected negatively, as water gets cooled down when passed through plant growing media, and
VII. Plants sometimes suffer excessive heat and humidity when the systems are combined.

4.3. Cage Culture

According to El-Sayed (2006), tilapia cage culture has been practiced commercially since the early 1970's. Currently, the use of cage culture for tilapia production is rapidly increasing. Specifically, in tropical and sub-tropical developing countries such as Africa, Asia, and Latin America. The success of cage culture depends on a number of factors, specifically water quality, stocking density, cage design, feeding programme, and feed quality. In African countries, a major challenge is the availability of suitable water sources, water quality, the cost of feed and the quality of feed that is available. As mentioned previously, the cage design is an important factor to consider. Sizes of cages, materials used, and designs vary from one operation to another depending on the scale of operation, available technology and capital, and expertise of the producer.

Commercial production cages range from six (6) to 20 m³ to very large cages up to 600 m³ in size. While certain research indicates large cages appear to be well suited for tilapia culturing, currently most cage culturing is done in small to medium sized cages. Stocking density in cages, as with other production systems can impact on the performance of the tilapia, however, in South Africa there is no record of tilapia cage culture operations, thus stocking densities used are based on African examples. Increasing the stocking density will increase the total yield, however, it will impact on the growth rates of the fish. Although cage culture is being used on a commercial scale, limited research has been conducted to determine the optimal stocking densities for cage culture. In Thailand, Nile tilapia was cultured at 30, 100, 300, and 500 fish/ m³ on weed based diets for three (3) months for research purposes. This study showed that the best production and profits were achieved at 500 fish/m³, however, the growth rates recorded were higher at lower stocking densities (El-Sayed, 2006).

Advantages of Cage Culture

I. Relatively low capital investment compared to other intensive culture systems,
II. Ease of observation, management, and early detection of stress and/or disease,
III. Ease of cage movement and relocation,
IV. Low cost, easy harvesting practices can be practiced,
V. Minimum fish handling and reduction of mortality,
VI. High stocking densities can be used,
VII. Improved growth rates have been recorded in cage culture, and
VIII. Optimum feed utilization has been recorded in cage culture systems (El-Sayed, 2006).

Disadvantages of Cage Culture

I. Risk of disease outbreak and difficultly controlling disease outbreaks,
II. Theft and vandalism,
III. Low tolerance of fish to poor water quality,
IV. Predation,
V. Complete dependence on manufactured feeds,
VI. Water exchange is essential to remove metabolic waste and maintain dissolved oxygen levels,
VII. Substantial amounts of feed are lost through the cages, and
VIII. Accumulation of metabolic waste and faeces under the cage can impact negatively on the natural environment (El-Sayed, 2006).

4.4. Flow Through Systems

Unlike the recirculating aquaculture system that filters and re-cycles water for re-use, the flow through system discards its water after use. Hence, the system relies heavily on constant or periodic water exchange, to flush out fish waste products. Exchange rates are determined by the available water quality and quantity, the fish biomass, and feeding rates. As a rule, the volume of water needed for a facility is the amount required to replace 100% of the tank water every 90 to 120 minutes (DeLong, et al., 2009).

Water for flow-through facilities is usually diverted from streams, springs, or artesian wells, to flow through the farm by gravity. Flow-through systems often are not ideal for commercial tilapia tank culture as tilapia are warmwater fish that grow best when the water temperature is maintained between 27 to 29 °C. Therefore, unless incoming water is from a geothermal source or is warmed, it will be too cool for optimum growth and heating large volumes of incoming water is generally not economically feasible. However, operations with a constant source of heated water, such as a geothermal or low-cost heat source, might be economically viable. Using surface water for flow through systems is not advisable, although there may be exceptions. The quantity of surface water available may vary during a drought season. The water quality may also vary from rainfall runoff, agricultural activity, or other development activity in the watershed area. Groundwater is a better source of water; however, it is advisable to gather as much history as possible on the water quality of a site before developing the culture operation. For example, water tapped from shallow wells may contain organic matter and unacceptable levels of ammonia or hydrogen sulphide gas. Geothermal water sources may have high levels of dissolved minerals that affect fish health. It might be possible to treat groundwater before using it, though the operator would need to determine whether or not treatment is economically feasible (DeLong, et al., 2009).

Advantages of using the flow through system

I. This aquaculture system can be operated with reduced levels of investment because the transportation of oxygen and waste will be done by the current of the water body, and

II. The fish grows under natural conditions.

Disadvantages of using the flow through system

I. The success of operating a flow-through system depends on natural conditions and environmental events,

II. The diluted waste from the system can also have an inadvertent influence of the downstream habitat,

III. The system is high-tech driven, thus requires a lot of energy which is not cost effective,

IV. Water discharged from flow-through tank systems may pollute receiving waters with nutrients and organic matters,

V. The discharge of effluent water into natural water bodies or dams may require a permit, with required periodic testing and oversight, and

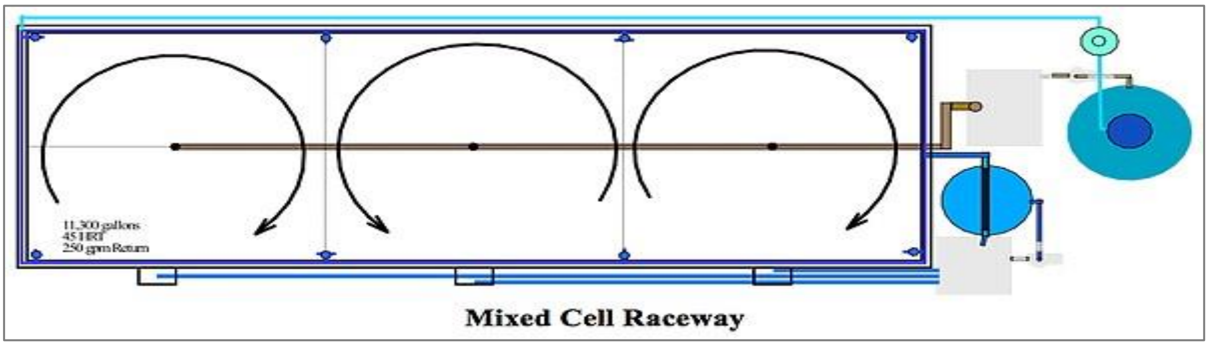
VI. The culture of tilapia in a flow through system can have higher labour and energy costs for pumping water and heating water, than pond culture methods.

4.5. Raceway Systems

Raceways are enclosed channel systems with relatively high rates of moving or flowing water. This high rate of water movement gives raceway systems a distinct advantage over the other culture systems. Tilapia can be cultured in raceways of varying sizes and shapes (circular, rectangular, square, and oval) (FAO, 2005 - 2017). Raceways depend on water flow to flush waste from the tank or series of tanks. For successful aquaculture, the inflowing water must be within the temperature tolerance of the tilapia and should match the optimal temperature as closely as possible. Oxygen is provided by the incoming water and is removed by the fish as the water progresses through the raceway. In most raceway systems, dissolved oxygen is replenished by allowing the water to fall into subsequent tanks within the raceway. Depending on the water chemistry, the depletion of oxygen and the accumulation of ammonia, carbon dioxide, or fine particulates can eventually become limiting to fish production within the system. No natural foods are generated in these systems, and nutritionally complete diets are an essential requirement for successful raceway aquaculture.

A growing trend is the use of mixed cell raceway systems for tilapia production, which has slowly been introduced, and successfully used in South Africa, as well as in the United States of America (USA). Mixed cell raceways are being linked to small-scale production operations and aims to provide an approach to grow multiple cohorts of fish in one tank. A mixed cell raceway operates a series of adjacent, counter rotating square or octagonal tanks, each with its own drain for the removal of solids, as seen in Figure 4-1 below. Through the design of this system, it should assist producers with maintaining water quality as the solids can be rapidly removed from each cell in the raceway, which will ensure water quality and fish health can be maintained.

Figure 4-1: Mixed Cell Raceway System



Source: Ripplerock Fish Farm,2018 (Online)

Through continued research and development, the use of mixed cell raceways for tilapia production is expected to increase globally, as it allows for improved management and efficiency in comparison with traditional raceways and pond systems (Ripplerock Fish Farms, 2017). The maximum tilapia density in raceways ranges from 160-185 kg/m³, and maximum loading ranges from 1.2-1.5 kg/litre/minute (FAO, 2005 - 2017) . A common production level in raceways is 10 kg/m^3/month, as water supplies are often insufficient to attain maximum rates. Production levels are considerably lower in tanks with limited water exchange, but water use efficiency is much higher in these systems. Most raceway operators believe they have more control over their fish production and see this as the major benefit of raceway culture. This control is achieved only if flow rate and water quality are relatively stable over time. In general, water cannot be economically pumped through raceways; it must flow through them by gravity. The need for large volumes of good quality water is the principal reason raceways have been limited to sites with large springs.

The typical raceway production system consists of a tank (rearing unit) or a series of rectangular tanks with water flow along the long axis. In an ideal raceway, water flow will approximate plug flow with uniform water velocity across the tank cross section. However, friction losses at the tank-water and air-water boundary layers will cause water velocities to vary across the width and depth of the raceway. Greatest water velocities are at mid-depth, with slightly reduced velocities at the air-water interface and greatly reduced velocities along the raceway bottom. Circular rearing units are more thoroughly mixed and have relatively uniform environmental conditions throughout the tank.

Advantages of using the raceway system

I. Improved stocking densities,
II. Ease of feeding,
III. Improved disease management, monitoring and treatment,
IV. Ease of harvesting and grading of fish,
V. Improved water quality,
VI. Quality and taste of fish can be improved in raceways,
VII. Lower labour requirements than other systems, and
VIII. More controlled system for producers to manage (Masser & Lazur, 1997)

Disadvantages of using the raceway system

I. High stocking densities can result in rapid spread of diseases and stock loss,
II. Less reaction time to deal with disease or problems within the raceway system,
III. Raceways require consistent, high quality water sources to maintain the system. This can be problematic in areas with water scarcity, or in drought conditions,
IV. Locating and securing a proper water supply is a major consideration,
V. Commercial viability often requires that the water gravity flows through a series of raceways before it is released. This adds a requirement for an elevation of the water source and suitable topography for the gravity flow between raceways,
VI. Large volumes of effluent with diluted fish waste requires well developed and managed waste management efforts to be in place, and
VII. Raceways have high energy usage, which increases operational costs (Masser & Lazur, 1997).

4.6. Pond Culture

When considering pond culture for tilapia in South Africa, it is important to note that currently only Mozambique tilapia can be produced in ponds, due to the invasive status of the Nile tilapia

The earthen pond is the most versatile culture system for extensive, semi-intensive, and intensive tilapia production, and one of the most popular production systems for tilapia. However, the pond culture is only economically viable in areas with a warm year-round climate, suitable land, and relatively large quantities of water (Norman-López & Bjørndal, 2010). Management of tilapia ponds ranges from extensive systems, using only organic or inorganic fertilizers, to intensive systems, using high-protein feed, aeration, and water exchange measures. In pond systems, the production cycle is dependent on the nutrient input rate. Natural ponds, where fish rely on natural food sources will normally have low stocking densities, and reduced growth rates, while ponds that are supplied with artificial feed, and/or fertilised can yield higher stocking densities, and faster growing fish.

Ponds can be fertilised to increase the natural food organisms, which would enhance production, however at a commercial scale, producers often combine artificial feed and fertilisers for optimal production. Commercial fertilisers can be applied at approximately 1000 – 1500 kg/ha, while organic fertilizer applications can exceed 2000 kg/ha (Boyd, 2004). Many semi-intensive farms rely almost exclusively on high quality feeds to grow tilapia in ponds. Male tilapia are stocked at 1-3 fish/m^2 and grown to 400-500 g in 5-8 months, depending on water temperature, climate, and water quality (FAO, 2005 - 2017). Dissolved oxygen is maintained by exchanging 5-15% of the pond volume daily. Higher yields of large fish (600-900 g) can be obtained by using high quality feed (up to 35% protein), multiple grow-out phases (restocking at lower densities up to three times), high water exchange rates (up to 15% of the daily pond volume) and continuous aeration (up to 20 HP/ha) (FAO, 2005 - 2017).

Advantages of using the pond culture system

I. The earthen pond culture system can be built wherever water with sufficient quality is available,
II. Low technology requirements – reduced operational and capital expenditure. Can be more forgiving then more high-tech systems,
III. Can be used in conjunction with other farming/agricultural activities,
IV. Non-productive land can be used for fish ponds,
V. Minimal labour requirements for pond systems,
VI. The fish are able to utilize natural food, and
VII. Fish can grow in ‘natural’ conditions.

Disadvantages of using the pond culture system

I. Ineffective use of freshwater system, specifically due to large volumes of water lost annually
II. Risk of uncontrolled reproduction that can lead to overcrowding and stunting of the Tilapia growth.
III. Ponds sometimes attract animals, such as birds and snails, they can bring parasites which may be detrimental to fish health,
IV. There is a greater risk of disease outbreak in pond systems,
V. Harvesting of tilapia can be challenging pond systems,
VI. Pond preparation and construction can be a lengthy process,
VII. Monitoring and management of fish can be challenging in pond systems,
VIII. Pond systems lose more water through evaporation and water loss than more controlled systems, and
IX. Provides less control over wild fish species invasion.

4.7. Culture Systems Summary

Having presented the advantages and disadvantages of various culture systems for tilapia production in South Africa, Table 4-1 below provides a summary for each production system based on the literature discussed. An indication of whether the system is viable or non-viable for tilapia production in South Africa is provided. Based on the system status, the generic economic model was developed to provide additional insight into the financial viability of the potential systems, which is discussed in the financial analysis chapter.

Table 4-1: Nile and Mozambique Tilapia Production Systems Summary

System	System Overview	System Status
Pond Culture	I. Suitable for commercial production II. Requires adequate size land for pond construction III. Most commonly used system by bulk of world's leading Tilapia producers IV. Relies heavily on artificial feed V. Major drawback is the risk of uncontrolled reproduction VI. Takes longer to prepare (excavate) and fill with water. VII. Provides less control over wild fish species invasion VIII. Minimum technological requirement & natural environment	Viable
Cages	I. Tested system II. Good growth performance III. Harvesting process simplified IV. Feeding programmes are essential V. No control over water conditions VI. Vandalism & poaching VII. Limited use in South Africa – potential for research	Viable
Aquaponics	I. Ideally suitable for commercial production, especially in urban areas II. Yield good growth/ development rates in aquaponic systems III. Fish growth is affected negatively, as water gets cool down when passed through plant growing media IV. Plants suffer excessive heat and humidity when system is combined V. Better fish growth is obtained in systems that are not integrated VI. Suitable for regions that exhibit feasibility for production but have less suitable resources such as water supplies, soil type or topography.	Viable
RAS	I. Ideally suitable for commercial production II. Requires high operating cost III. Depends solely on artificial feed and not naturally enhanced food IV. Dependence of energy- consuming life support systems V. Cost of installing and operating alternative energy systems is high VI. The technology is more viable in other countries (Europe/USA) due to higher fish prices VII. Assists with biosecurity control VIII. Allows for intensive aquaculture operations	Viable
Flow-through tank based systems	I. Not an appropriate technology to Tilapia culture because of temperature control II. Incoming water needs to be heated or channelled through a geothermal source. Geothermal water sources may have levels of dissolved minerals that affect fish health III. Constant heating of large volumes of incoming water is not economically feasible IV. System is prone to drought especially when surface water body is used V. Surface water quality may be impacted by other activities in the	Non-Viable

	watershed area VI. Discharge of effluent water is costly & may require permits	
Raceways	I. Potential to investigate use of mixed cell raceways in South Africa II. Higher stocking densities than other systems III. Offers good feeding and production observation IV. Harvesting and grading is efficient and easier to manage V. Heavily reliant in artificial feed VI. Requires large volumes of water – can be challenge specifically in dry or drought conditions VII. System results in high energy costs VIII. Waste water management and permits required for raceway effluent IX. Water management and quality is essential for fish health and production	This production system requires further research to determine the viability of the system in South Africa.
Ranching	N/A	N/A

5. Nile and Mozambique Tilapia Market Assessment

Nile & Mozambique Tilapia are both discussed under the market species under the broad term of "tilapia" as no differentiation is made between the two species at a market level

In this section of the report, the tilapia industry, and its role in the market, will be assessed. The section will cover the production and consumption trends of tilapia - both globally and locally; the marketing channels, and the market requirements of the industry. The tilapia market deals with the distribution of the ***cichlid fish***, the actual number of species within this family is unknown but is estimated to be around 2000 to 5000 species. In this analysis, the two-main species considered are, the *Nile and Mozambique tilapia.*

Tilapia, which is considered as an alternative white fish to hake, has outstanding appeal to consumers globally; with the consumption of tilapia present in almost all continents. Tilapia are the second most commonly farmed fish (after carp), in the world; the species is also appropriate for resource poor farmers in tropical areas, among other factors mentioned throughout the report, that contribute to its popularity (Seaman, 2016; Murnyak, 2010).

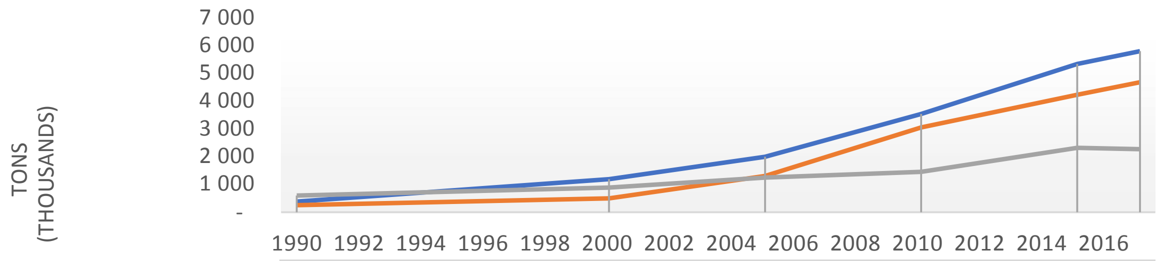
5.1. Production and consumption

Production and consumption considers the global, regional, and local supply, demand and consumption trends and patterns for tilapia.

5.1.1. Global Supply Analysis

Globally, over the past few decades, the production of tilapia has been thriving, and has been dominating the global aquaculture sector since the late 2000's in comparison to other key species such as Salmon and Catfish as seen in Figure 5-1 below.

Figure 5-1: Global production of some major farmed fish – comparative analysis (1990-2017[6])



	1990	2000	2005	2010	2015	2017
Tilapia	379 000	1 190 000	1 992 000	3 541 000	5 339 000	5 798 000
Catfish	250 000	500 000	1 302 521	3 056 400	4 228 000	4 676 000
Atlantic Salmon	600 000	893 704	1 250 700	1 455 200	2 314 600	2 269 500

Sources: Tveteras, 2016; Fitzsimmons, 2016; FAO,

An increase in production levels, of about 1.2 million tons, recorded in 2000 to about 5.8 million tons in 2015 (a growth of approximately 387% over a 15-year period) is evident which highlights the growth potential of the aquaculture industry. This astonishing increase in production can be

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[6] *2016 & 2017 are forecasted based on 2015 data that was sourced*

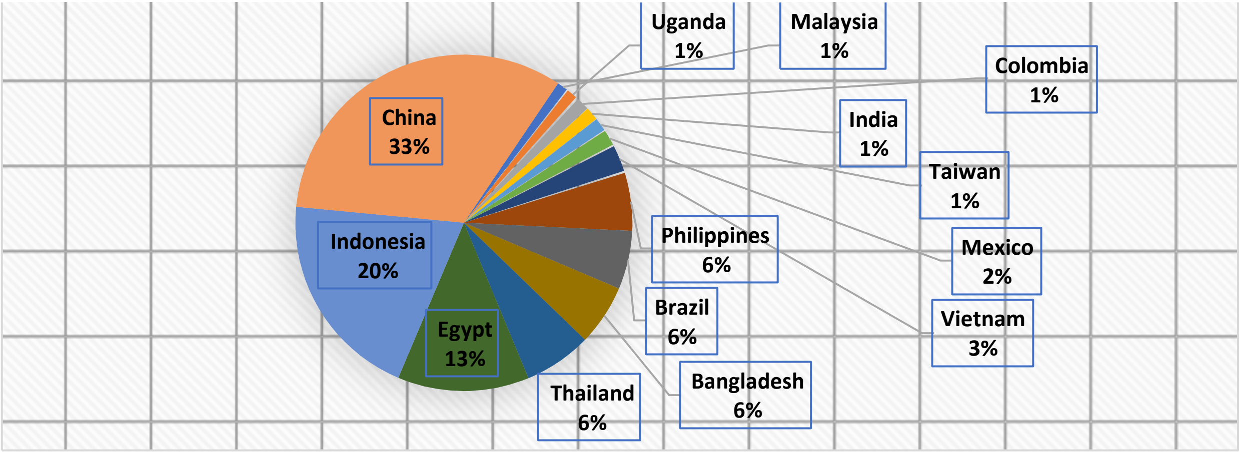
attribute mainly to technological improvement in the aquaculture industry (which has led to an increase in production efficiencies – this encompasses improvements in processing and packaging, traceability, and environmentally safeguarding), and market growth - experienced mostly in the United States of America (USA) and Asia (Fitzsimmons, 2016; Tveteras, 2016).

The ***dominant continents*** in terms of tilapia production during 2015 were:

- Asia – accounting for 78% of global production (with about 4 million tons),
- Africa – accounting for 14% of global production (with over 700,000 tons), and
- South America – accounting for 9% of global production (with about 450,000 tons) (Seaman,2016).

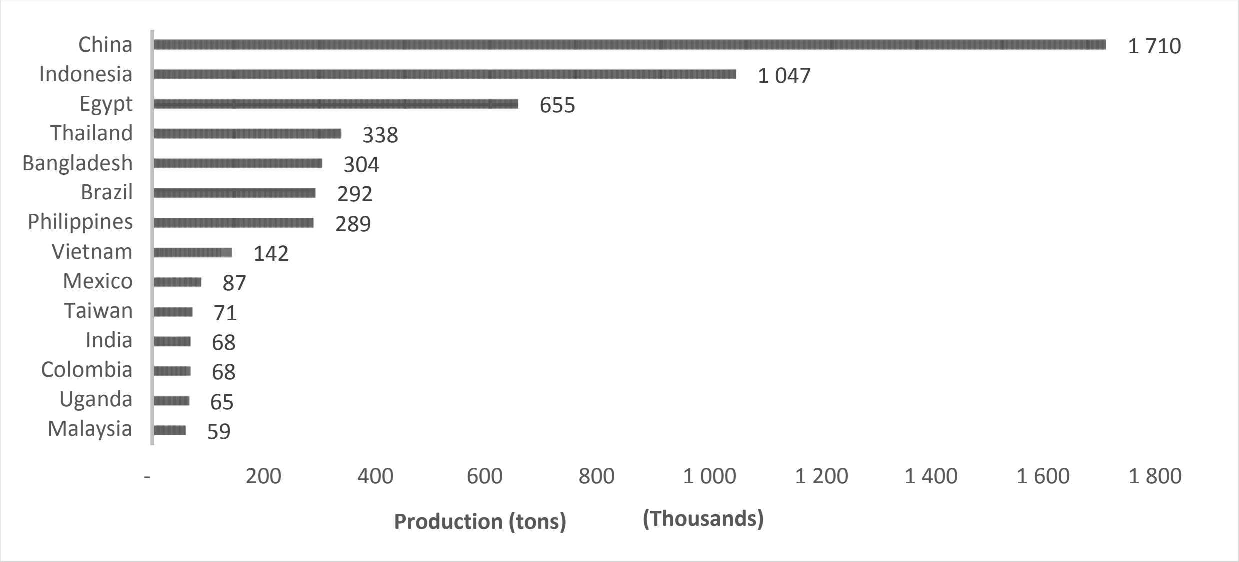
The ***key tilapia producing countries*** were **China**, who dominated the market with over 30% of total global production (1.7 million tons), followed by the **Indonesia** with 20% (1,046,657 tons), and **Egypt** with 13% (655,350 tons) of the total global production. Other key producers included Thailand, Bangladesh, Brazil, and Philippines, of which each holds approximately 6% of the global production (refer to Figure 5-2 and Figure 5-3 below).

Figure 5-2: Production ratio of top producing countries during 2015



Source: Seaman, 2016

Figure 5-3: Top Producing Tilapia Countries, 2015



Source: Seaman, 2016

The production of tilapia is expanding, specifically in Asia and South America where significant volumes of tilapia are consumed by the growing domestic markets. Growth in the production of tilapia is currently occurring and foreseen to continue expanding in the following countries:

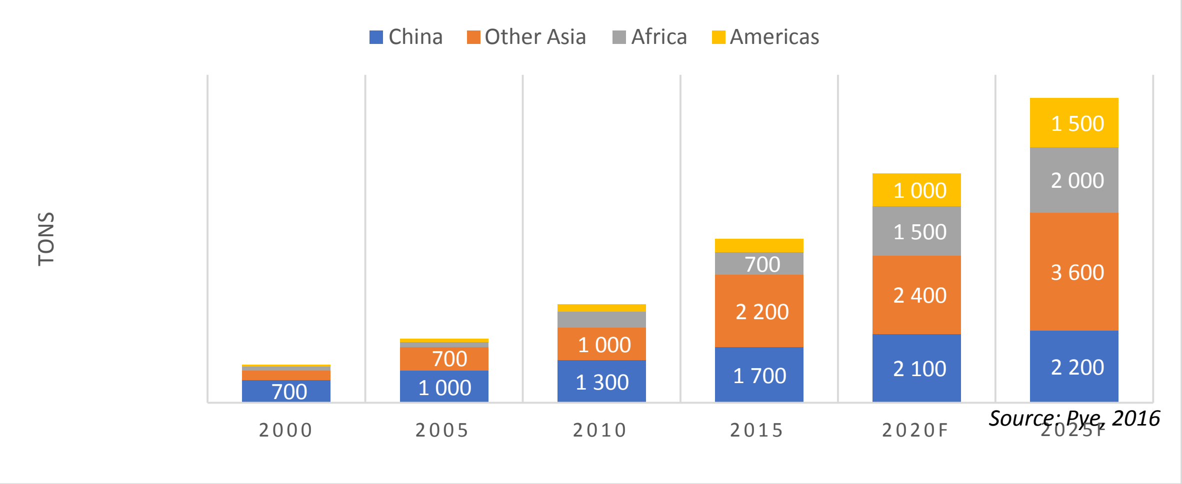
- **Indonesia** – Currently focuses on cage culture, polyculture and rice culture and have the fastest globally growing industry,
- **Vietnam** – Due to conversions of catfish cages into tilapia operations,
- **Malaysia** – Due to government support and private sector investment,
- **Bangladesh** –Supported by government and private sector investment,
- **Brazil** – Due to vast water resource, labour, land, and feed; which implies cheap cost of production, and
- **Mexico** – Which continue intensification of production and enjoy some government support coupled with private sector investment (Fitzsimmons, 2016).

On the contrary, China has experienced rather sluggish production volumes recently, with lower production and processing volumes recorded since 2015, reflecting a slow market growth in recent years specially in the USA and Mexico which are the main channels markets (FAO, 2016 and Wietecha, 2016). In summary, global tilapia production is projected to grow in the smaller tilapia producing countries such as Brazil, Mexico, Vietnam, etc, while leading producers such as China will become more dependent on developing their own domestic markets in the future.

5.1.2. Global Demand Analysis

Information on market demand is fragmented and outdated in many cases; however, it is evident that the Chinese market has the largest domestic market for tilapia, consuming an estimated 33% of the tilapia produced globally. Furthermore, current trends show that other Asian countries are becoming major markets as well as additional new markets in South America and Africa are likely to become globally dominant as can be seen in Figure 5-4 below (Pye, 2016).

Figure 5-4: Key Global Markets for Tilapia

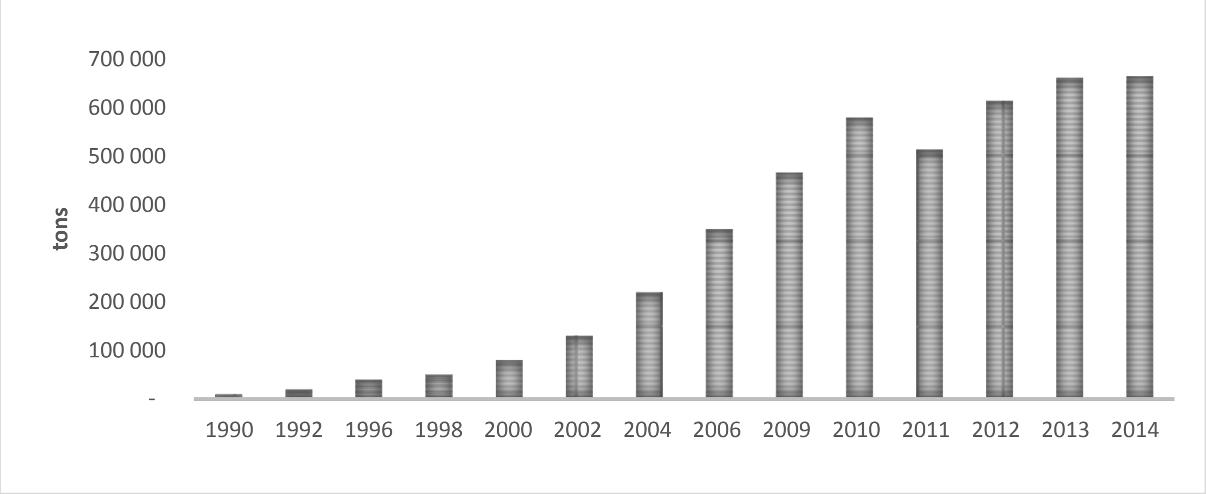


Source: Pye, 2016

The Asian domestic markets are increasing in size, specifically from the East in China to the South in Bangladesh, as well as Hong Kong, Taiwan, Malaysia, and Singapore. The preferred tilapia products among these markets are “live”, “whole”, as well as the “fillets” served in supermarkets, seafood restaurants, and the hospitality industry (Ferrous, 2013).

The USA maintains its position as the world's single largest importer of tilapia, with tilapia products remaining very popular at the retail shops. Consumption trends show continued growth from 465,953 tons during 2009 to 633,759 tons in 2014 (Fitzsimmons, 2016). In the USA, a rapid increase in tilapia consumption was seen from the early 1990's to 2010, followed by a decrease in consumption in 2011, as seen in Figure 5-5 below. The rapid growth can be attributed to the introduction of affordable products imported from time, which had saturated the USA markets by 2010.

Figure 5-5: USA Tilapia consumption



Source: Fitzsimmons,2016

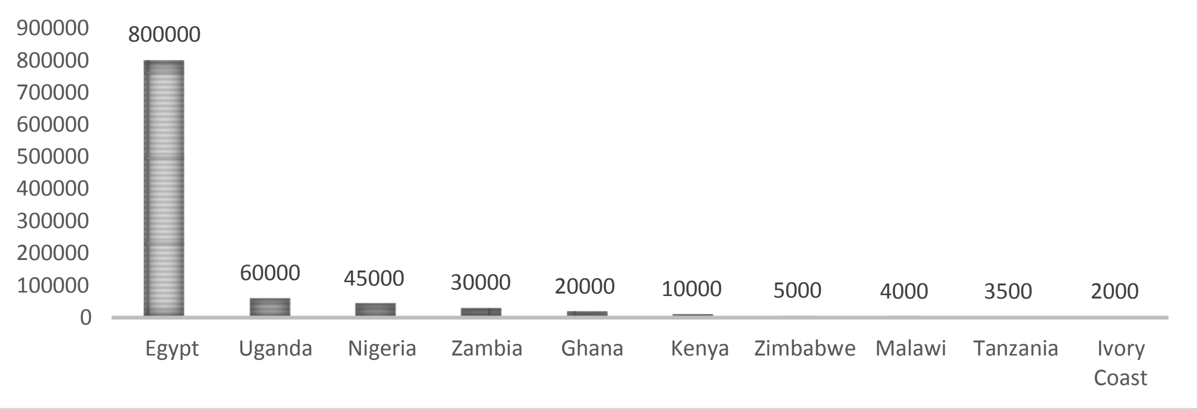
The total market value that was recorded for tilapia ranges from approximately USD 400 million during 2005 to about USD 1,114 million in 2014; which again highlights the rapid growth of the industry (Fitzsimmons, 2016). The market value increased despite the slower growth in the quantities supplied, this could be explained by the increase of value-added frozen fillet products or the increase in the demand for the product. The South and Central American countries export mainly to Brazil and Mexico. Brazil, which has a per capita consumption rate of 10 kilograms per person, is importing about 30% of its consumed fish. While Mexico, which is the second largest importer for China's frozen products, is expected to expand on the fresh products in future (Fontes, 2016).

5.1.3. Regional and Local Production

Tilapia, which is a native species to Africa, is one of the most exploited inland water fish species on the continent. Within the Sub-Saharan regions, tilapia is largely supplied through traditional freshwater capture resources such as rivers, dams, lakes etc. Tilapia supplied through farmed production is still not commercialised in many African countries. Despite the public sectors limited involvement to promote Tilapia production, the sub-sector has grown at an average rate of 20% over the last decade and is presently the fastest growing aquaculture sub-sector in the Sub-Saharan region. In 2012, about 150 000 tons of tilapia were produced through aquaculture in the Sub-Saharan region (Mapfumo, 2015). The leading African countries in tilapia production include, Egypt, Kenya, Nigeria, Uganda, Zambia, and Zimbabwe, who have all recorded notable growth in commercial aquaculture production in 2014. The dominant part of production remains controlled by the small-holder producers either in their backyard for subsistence purposes, or small-scale commercial ventures, using various production systems. Commercial tilapia operations are mostly found in Ghana, Zambia, Zimbabwe, and Uganda (Mapfumo, 2015).

Apart from Egypt, which is the third largest global producer of tilapia; Africa's top tilapia producing country is Uganda with about 50,000 tons produced during 2014, followed closely by Nigeria (40,000 tons), and with Zambia and Ghana about 30,000-20,000 tons each. Kenya, Zimbabwe, Malawi, Tanzania, and Ivory Coast have all low production of a few thousands of tons as seen in Figure 5-6 below. In addition to Egypt being the largest tilapia producer in Africa, is also considered to be one of the larger domestic markets in the region, consuming most of its local tilapia production (Widiarti, 2015).

Figure 5-6: Tilapia production in Africa during 2014



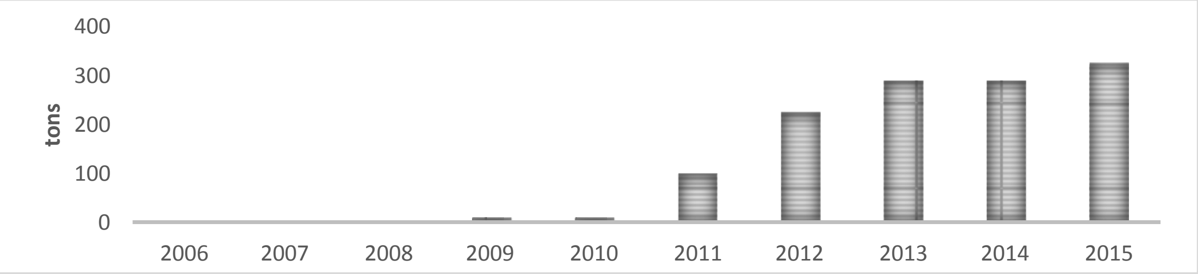
Adapted from (Mapfumo, 2015)

Having considered the top producing tilapia countries in Africa as seen in the figure above, it can be said that South Africa experiences very low production volumes by comparison. Tilapia is growing in popularity for aquaculture due to the market qualities it offers producers and consumers alike. Key qualities tilapia offers includes:

- White meat in a similar class as hake, and Pangasius,
- High quality meat that has good market acceptance,
- Versatile taste and texture which offers opportunities for fresh products (fresh whole fish or fillets), and value-added products (smoked, dried, or frozen products), and
- Meat colour can be influenced by production and feeding programmes to suit consumer preferences (Stander, 2012).

This sub-sector contributed approximately 18% to South Africa's total freshwater production, recording 325.29 tons during 2015 (DAFF, 2016). However, although the tilapia industry is still at its infant stage in regional and global terms, it has shown substantial growth since 2011 as can be seen in Figure 5-7, below.

Figure 5-7: Tilapia production in South Africa (2006-2015)



The majority of the tilapia farmers in South Africa are considered to be small-scale farmers and they predominantly utilise either a recirculation systems or pond culture method to produce tilapia. The total number of recorded farms in the industry during 2015 was 74 which jointly produced 325.29 tons (DAFF, 2016). The increase in the number of tilapia farmer since 2013 and the increasing production levels indicates that the industry is steadily expanding (IDC, 2015). Tilapia producer's face constraints regarding market access, which can be attributed to the size of the sub-sector, as well as the low volumes being produced. It is estimated that tilapia producers are currently producing an average of ten (10) tons per producer (Britz and Venter,2016).

5.1.4. Regional and Local Consumption

Tilapia is a traditional and favourite dish in almost all countries of Sub-Saharan Africa. However, little is known about the current tilapia markets in Africa, in terms of the sizes, specific locations, and trade scales due to scanty data. What is clear is that nearly all Tilapia that is produced in Sub-Saharan Africa is locally consumed, with very limited exports to overseas markets (such as USA and EU). The average fish consumption rate in the Sub-Sahara region is estimated at about 10 kg per capita, in comparison to other countries such as Asia (whose consumption per capita is 21 Kg), Europe and North America (at 22 kilograms per capita). Despite the relatively low consumption volumes, the Sub-Sahara region is an emerging global market for tilapia; with an estimated market size of about 1.5 million tons of tilapia to be consumed by 2020. Key factors that are contributing to this increase in demand is the rapid rate of urbanization taking place in the continent and high levels of migration (specially from Asia with an impact on the demography of some areas), the increase in standards and buying power, and the increase in infrastructure development (e.g. access to market through better road networks) (Mapfumo, 2015; EUMOFA, 2015; Pye, 2016). Noticeable countries with a strong domestic demand for tilapia include the DRC, Ghana, Malawi, Nigeria, Rwanda, Kenya, Uganda, and Zambia. Some fact about key African markets include (INFOFISH, 2015):

Angola

- Rapid increase in population from 13.8 million in 2001 to 28.8 million in 2016, implies large scale market (The Worldbank, 2017),
- 16.3 kg per capita consumption of fish in 2013,
- Significant buying power- Angola is classified as an upper middle-income state by World Bank (per capita income over US$ 4000),
- Angola market is estimated to be shortfall of >10 000 tons of Tilapia,
- The data presented is combined from informal and formal markets, and
- All forms of Tilapia products are consumed including: Dried, Frozen, Fresh, and Fillets.

DRC

- Demand for fish is higher than the domestic industry can supply with an estimated shortfall of >30 000 tons of tilapia,
- Fish provide approximately 25-50% of the country's protein requirements,
- Huge population of about 78 million in 2016 (The Wold Bank, 2017),
- Large immigrant population from China in Eastern DRC has become an important new market for imported fish and fishery products
- Preferred products are both fresh and whole fish, however dried and frozen products are common, and
- Market is mainly informal and much of the trade is done at local fish markets.

Ghana

- Demand for fish is higher than the domestic industry can supply,
- Tilapia is a top favourite dish in Ghana, and fresh produce is preferred,
- Ghana market is estimated to have shortfall of >20 000 tons of tilapia, and
- The market is made up of formal (restaurants, retail, and fish stores), as well as informal fish markets.

Malawi

- One of the biggest countries affected by shortage of fish in Africa due to decline in wild stocks (Catches from Lake Malawi have declined by over 90% since late 1980's),
- Large market size - In 12 years the population has increased from approximately 10 million people in 1998 to current 18 million in 2016 and at the current growth rate, is projected to reach over 26 million by 2030 (The World Bank, 2017),
- Demand for fish is higher than the domestic industry can supply. Fish provide nearly 30% of the country's protein requirements,
- Malawi market is estimated to have shortfall of >10 000 tons of tilapia,
- Preferences for fresh supply, and specifically for the local species ("Chambo"),
- Well established distribution network (significantly through informal traders), and
- Market is formal (retails shops) and informal local fish markets.

Nigeria

- The biggest economy in Africa,
- Largest market in Africa - over 186 million people (2016),
- Local market (formal and informal) is consuming all local production (about 20,000 tons of Tilapia) and additional importation from China of frozen products,
- Fresh whole fish are preferred (i.e.: receive high price), but frozen and dried are also typically consumed, and
- The country reported to have general well-developed fish distribution systems and infrastructure.

Uganda

- One of the larger markets in East Africa - Population is 41 million (The World Bank, 2017)
- Fish consumption is 13.6 kilograms per capita,
- Tilapia is a traditional dish in Uganda. The preferred form is fresh whole fish however, dried, and frozen are very common in the local market, and
- Significant informal local market (including several fish markets) strongly supported by the informal local and regional traders.

Zambia

- Has been one of the world fastest growing economies since early 2000's,
- Has witnessed rapid increase in volumes in aquaculture production, less than 8 000 MT in 2010 to over 20 000 MT in 2013, mainly tilapia consumed locally,
- Demand for fish is very high, a recent study put per capita consumption at over 25 kilograms,
- Large commercial farms (e.g.: Lake Harvest Aquaculture) supply fresh products into the local and regional markets,
- Major quantities of frozen whole (mostly imported from China) are being redistributed into the local and regional markets,

- Well established distribution channels into and out of the countries (mostly through informal traders) make Zambia a trade hub for Tilapia in the SADC region,
- Zambia market deficit is estimated at more than 50 000 tons of fish, and
- Niche market due to Asian migration - Based on data from the census in Zambia, there are approximately 100 000 Chinese people in Zambia (mining & infrastructure development).

Having reviewed the regional consumption trends, the next section will focus on the consumption trends of South Africa. Based on published data during 2015, South Africa local consumption of tilapia is set at 3041.86 tons per annum, and was calculated as follows:

Table 5-1: South African Tilapia trade and estimated local market

Domestic consumption	Tons
Tilapia Imports	3042
Tilapia Exports	325.43
Local production of Tilapia	325.29
Total	**3041.86**

Adapted from DAFF,2016

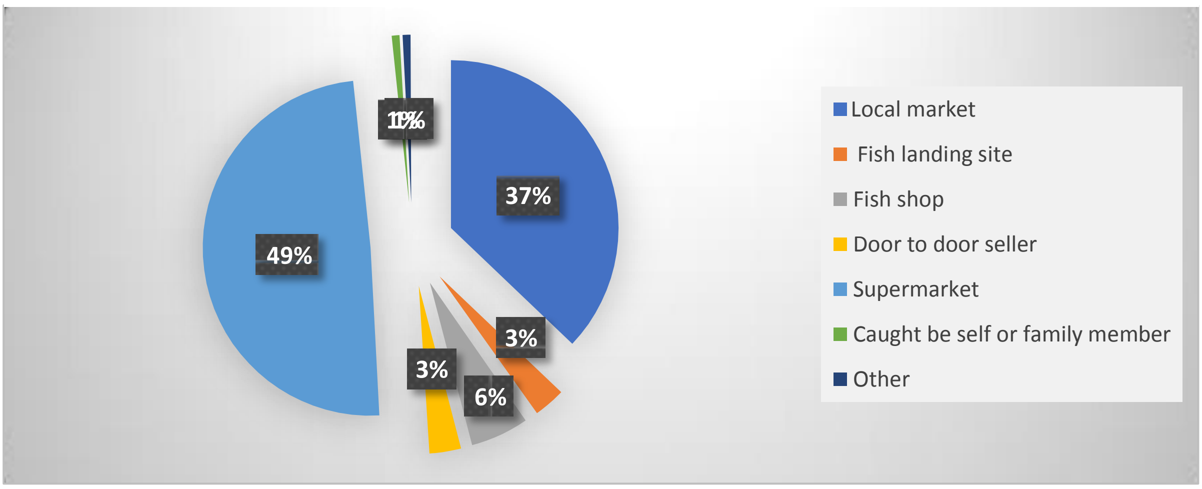
From the table above, the South African tilapia market can be seen to be underdeveloped from a regional and international perspective. Furthermore, the South African white fish consumption market is dominated by the country's well-developed fisheries, and in particular, hake. The hake market could be an additional opportunity for the tilapia local producers. In recent years there has been an increased level of interest, and potential for tilapia off-take agreements were recorded with the main retail outlets (such as Pick and Pay and Woolworths) if quality, quantities, and prices can meet those of the hake supply (IDC, 2015).

In recent years, there has been a noted change to markets as there is a need to increase South Africa's consumption of freshwater fish. Retailers are now presenting farmed tilapia in various forms such as fish fillets, seasoned and packaged in ready to cook format to increase consumer interest and improve sales. While fresh tilapia products are well-received in more upmarket retailers and restaurants, the market remains relatively small due to low production volumes in the country (Britz & Venter, 2016).

Based on survey conducted during 2015 in Gauteng by WorldFish, initial patterns of consumers provided an insight into the market channels of fish trade in the province, of which tilapia is a dominant species. The survey revealed that consumers purchased fish from several sources, including (Gondwe, 2017):

1. An average of 49% of consumer in the survey bought their fish from supermarkets,
2. Local markets were also another common point of purchase with about 37% of consumers selecting local markets,
3. Fish shops were the main source of fish for about 6% of respondents (which was mainly supplied fish products not available in supermarkets, such as catfish),
4. The form of fish products mainly found in local markets were dried products such as dried tilapia, carapao and catfish, and
5. Other sources such as door-to-door sellers and fishers had low contribution levels to the market in Gauteng.

Figure 5-8: Consumer Patterns: Purchasing of fish products in Gauteng (2015)



Source: Gondwe,2017

As the supply of fresh tilapia products is somewhat limited, the need for imported products remains high in South Africa, with the FAO indicating a shortfall of 10 000 MT of tilapia. Imported frozen whole fish mostly from China, India, and Lake Harvest from Zimbabwe is sold mainly through the formal distribution retail channels e.g.: Pick and Pay and Food Lovers Market or through informal shops/stands on the side of the roads (refer to images below) (Valdi Pereira, 2017).

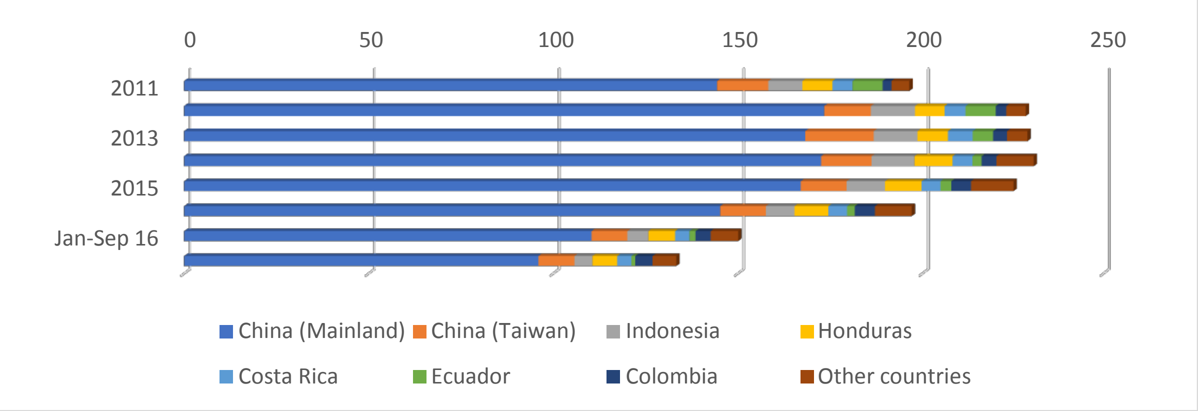
5.2. Marketing channels

Market channels look at the key global, regional, and local marketing channels for tilapia that are important to understand in terms of trade, major producers, and the flow of products between countries. The generic economic model takes both local and international markets into consideration and offers flexible pricing options which are dependent on the size of the fish being produced and the target market identified. The pricing of the fish, and the target market impact on the financial results obtained when using the generic economic model, as these two factors play a key role in determining the profitability of an operation. Understanding the markets, pricing and preferred products for the market is essential.

5.2.1. Global Tilapia Trade

Globally, the biggest import market is the USA. The USA market is mostly supplied by frozen product from the Asian countries (China, Indonesia) and fresh products from the Central and South America (i.e.: Mexico and Brazil) as can be seen in Figure 5-9 below. On the other hand, China is today the largest exporter, with most of its products imported into the USA (56% during 2012), with Mexico being its second biggest market (10%), EU and Russia following each with 6% of total Chinese exports (Fitzsimmons, 2016). The African imports remained strong in 2016, with some 64% of Chinese whole frozen tilapia and 17% of Chinese breaded tilapia being imported (FAO,2016). While the African market, and Iran continue to show growth, the USA imports of frozen tilapia from China have declined, from an estimated 75% in 2005 to 42% in 2015. This decline is being attributed to the decrease in supply of frozen goods from China, as well as market saturation being experienced due to consumer preferences and market conditions (Wietecha,2016; FAO,2016) According to sources, Mexico and Brazil are focusing on the export of fresh, whole fish products to the USA, which will impact on the need demand for frozen fish products in the USA – China trade patterns (Towers,2017).

Figure 5-9: USA Tilapia Imports 2011 – 2017 (Tons)

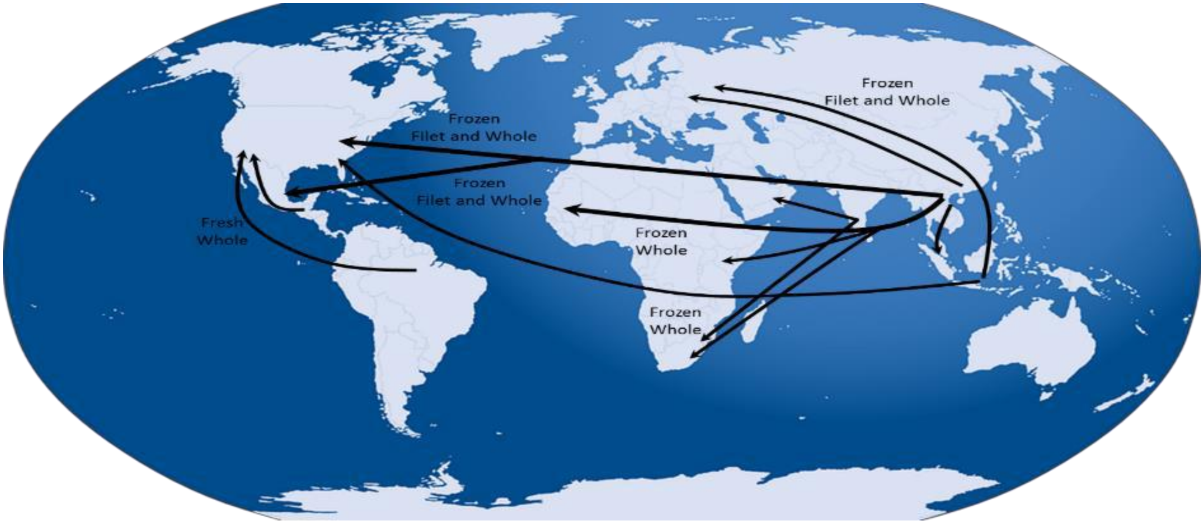


Source: United States Department of Agriculture,2017

Indonesia, which is the second largest tilapia exporting country into the USA after China (which focuses on value-added products such as fillet), recorded a trade value of about USD 70 million during 2014. Indonesia is also a major exporter of frozen fillets into the EU, with key countries including: Netherlands, Germany, and Belgium (Widiarti, 2015).

Other markets, such as India reported exports to the Middle East (United Arab Emirates, Saudi Arabia, and Oman) as well as South Africa (Towers, 2017, DAFF, 2016). Globally the key tilapia exporting regions are Asia (including key countries such as China, Indonesia, and Thailand) and South America (featuring mostly Mexico, and Brazil), as seen in Figure 5-10 below. (GLOBEFISH, 2017; Fitzsimmons, 2016; Pye, 2016; Ferdouse, 2013).

Figure 5-10: Global Tilapia trades pattern and products types



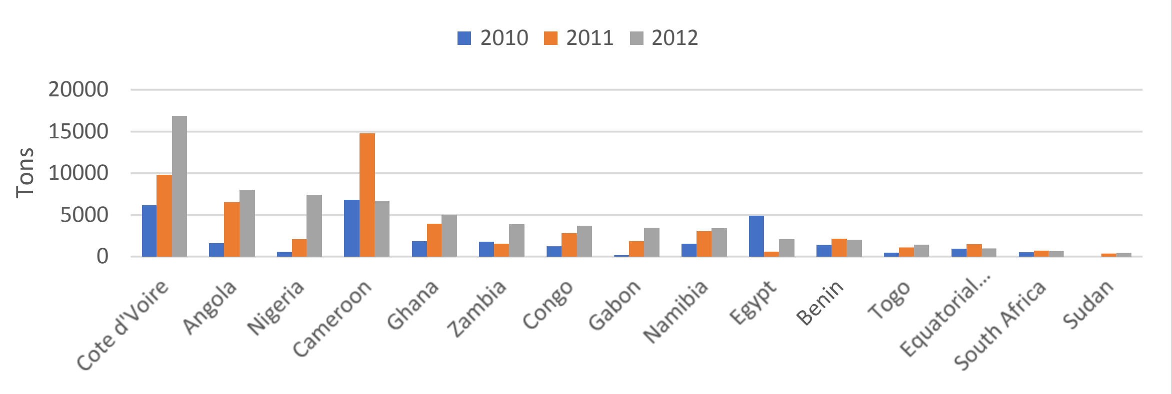
Adapted from: GLOBEFISH, 2017; Fitzsimmons, 2016; Pye, 2016; Ferdouse, 2013

As seen in the figure above, very limited tilapia exports originate from Africa, as the African markets tend to target their local markets and meet the local demand. As the largest producer on the continent, Egypt only supplies its local market. The figure above, highlights the need for growth and improved production in the tilapia industry, specifically in African and South Africa, who are reliant on imports to meet the current demand. In 2016, it was estimated that Africa imported 83 000 tons of whole frozen fish products (Globefish,2017).

5.2.2. Regional and Local Trade of Tilapia

The Sub-Saharan tilapia demand is outstripping the regions local supply. The African markets have experienced a massive influx of exported products from China as seen in Figure 5-11 below. The current export volumes of Tilapia into Africa are currently unknown however, from 2013 records it is evident that the Chinese exporters have managed to penetrate many key markets in the continent and their trade is rapidly expanding. Significant trade is noted with the West African regions (about 67%) of the total export to Africa, and specifically with Cote d'Voire which is currently considered to be the third biggest export market for China after the USA and Mexico (Towers, 2017). The Chinese exports have also managed to penetrate key African markets such as Angola, Nigeria, and Cameroon.

Figure 5-11: Tilapia exports from China to African markets during 2010-2012

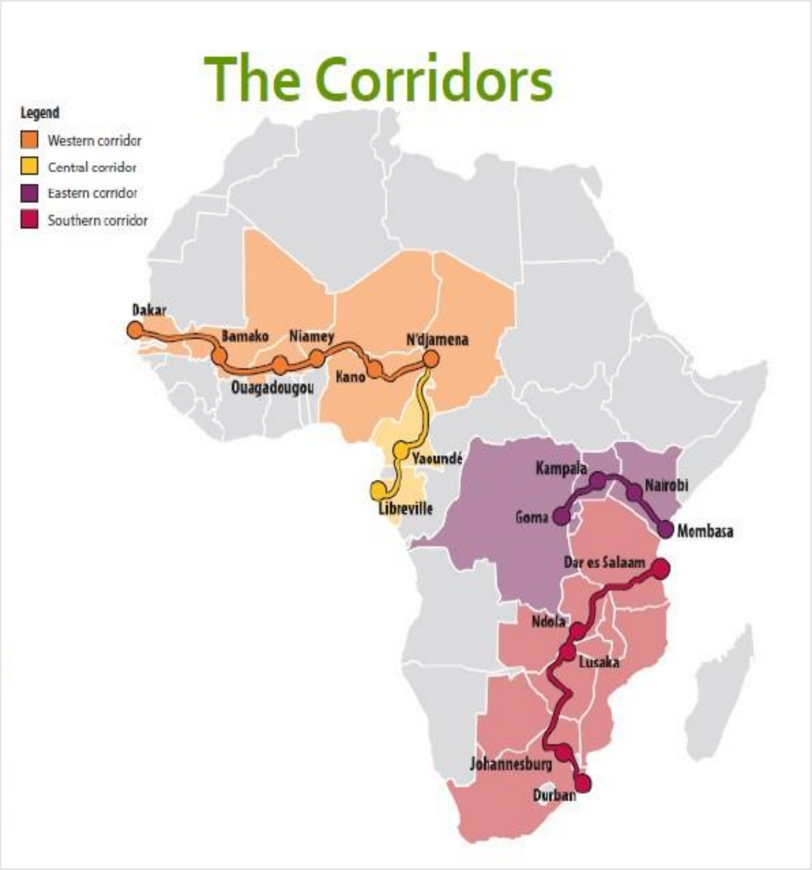


Source: Ferdouse,2013

Intra-regional trade in Africa is still a key component in the tilapia industry, and major part of it is being done by small-scale informal traders who have become important players in the tilapia distribution chain (Mapfumo, 2015; Banda, 2016). Recent joint research (by World Fish, AU-IBAR and NEPAD) aiming at defining the region trade dynamics to improve public and private sectors engagements with the markets, have identified four fish trade corridors in sub-Sahara Africa (involving 21 countries – see Figure 5-12).Specifically, with regards to tilapia, the study confirmed the influx of tilapia from China through South Africa and Namibia, which is then re-exported into Zambia who act as a "hub of distribution" into DRC and Malawi markets as shown in Figure 5-12 below (Banda, 2016).The tilapia markets in Sub-Saharan Africa are diverse, which range from small-scale localised African markets (e.g. at farm gates and roadside market stalls) to more sophisticated commercial distribution chains and depots linked to large retail chains selling a range of product forms including value-added products (Mapfumo, 2015, INFOFISH, 2015).As mentioned earlier, the South African trade is limited with its local low production and is mostly dominated by the re-exporting of Chinese goods further north in the continent. The local production trade is very limited to several tons mostly sold as frozen whole fish in Zambia and through a local distribution network aiming to be re-sold on the DRC markets (Personal Communication,2017).

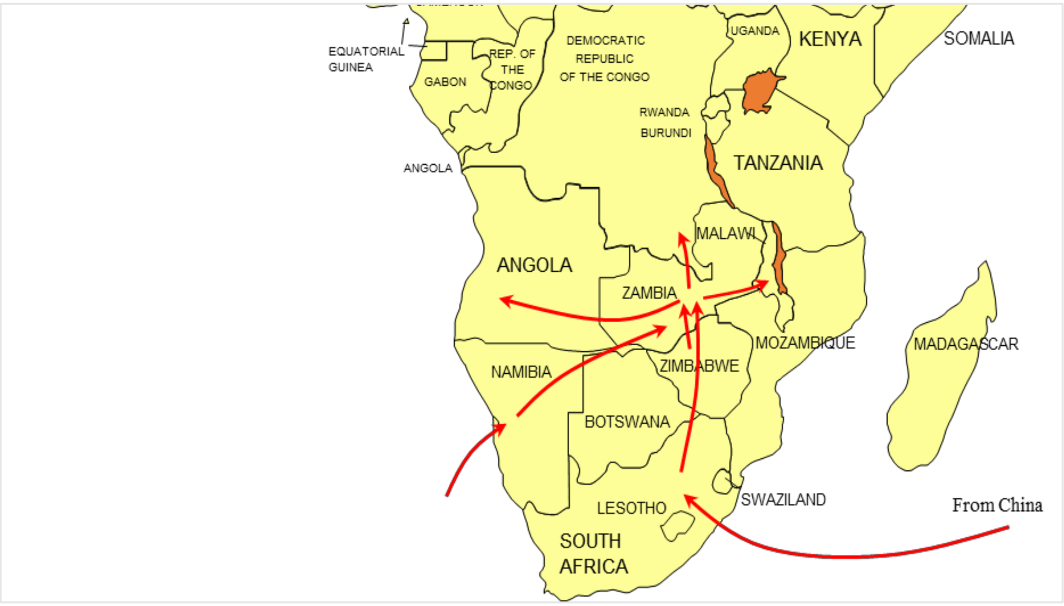
The South African production and trade of tilapia is limited due to factors such as unsuitable environment temperature regimes, an underdeveloped tilapia value chain, legislation, and high production costs, which is discussed under market barriers. The need for increased focus on product development and marketing strategies has been identified, if South Africa wishes to compete at a regional and international level (Britz & Venter, 2016).

Figure 5-12:Intra-regional fish trade corridors in Africa



Source: Banda; World Fish 2016

Figure 5-13: Tilapia Trade flows in the Southern African region (2014)



Adapted from Banda, World Fish 2016.

5.3. Market requirements

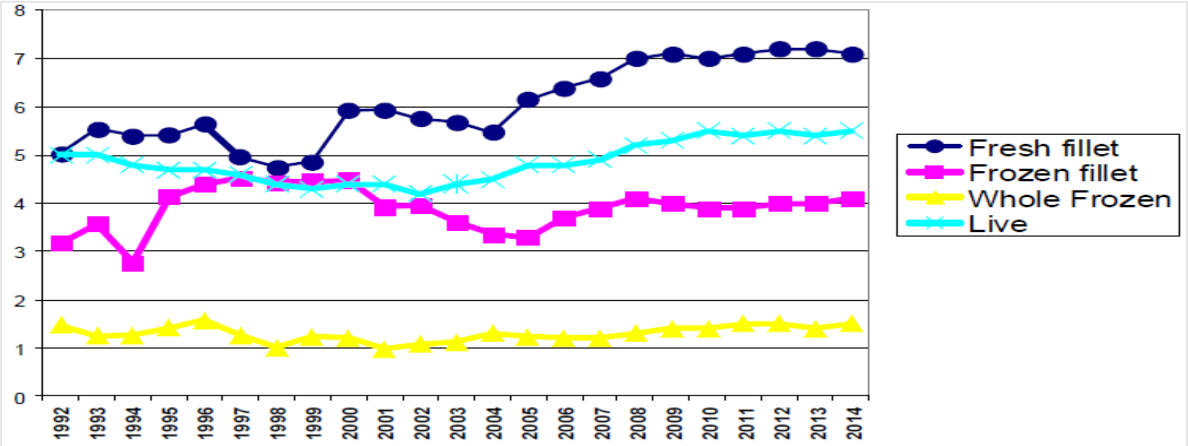
Market requirements look at the status of global and local markets to provide an overview of consumer and market preferences, as well as the potential market opportunities that can be targeted by the tilapia industry.

5.3.1. Global Markets

The tilapia products consumed by the USA market are a mix of frozen and fresh products which are made of mostly: frozen whole fish (average plate size), frozen fillets, and fresh fillets. Since mid-2000’s the USA market has been dominated by frozen fillet products, with an increasing amount of fresh, whole fish products being consumed (Fitzsimmons, 2016). Prices trends in the USA of fresh fillet, frozen fillet, whole frozen and whole live recorded between early 1990’s and 2014 reveals the following as seen in Figure 5-14 below:

- Since early 2000’s prices of all products did not increase significantly beside the fresh fillet which has increased by approximately 15%, reaching an estimated USD 7.45/kg in 2015. This indicate the preferences of the American market to top fresh fillet quality. It could also indicate some shortages of supply from key supplier such as Mexico,
- Whole frozen products have experienced a decline in prices in the USA market, reaching USD 2.11/kg in 2015, down from USD 2.49 in 2014. The price decrease is being attributed to demand in the USA, market saturation from Chinese frozen products, and the devaluation of the Chinese Yuan (FAO,2016),
- Frozen fillet price is stagnant around the USD 4/Kg from 2009-2014, indicating lower demand, and
- Overall fresh products price (whole or fillet) are supreme to frozen products in the USA.

Figure 5-14:Price (USD) trends in the USA market between 1992-2014



Source: Fitzsimmons,2016

In the EU market the preference is somehow different, as frozen or processed value-added fillets are dominant (with minimal fresh tilapia available). The EU market has been dominated by frozen fillets, however with changing consumer lifestyles, and time constraints facing consumers, the focus is shifting to value-added, convenience food, which has increased the demand for prepared or pre-cooked, marinated Tilapia products (CBI-Ministry of Foreign Affairs, 2015). The EU market is very sensitive to quality and high prices, and as a result, Tilapia products face strong competition from Pangasius products as they offer lower prices for the same quality (Globefish, 2017).

During 2016, the EU-27 market imported 12,300 tons of tilapia of which 56% frozen fillet and 44% whole frozen, and a small volume of fresh tilapia fillets (Towers, 2017; FAO,2016). It is evident, that like the USA market, the Asian and South/Central American markets have a clear preference for fresh products mostly whole fish (average plate size). The markets demand is high with attractive prices, as indicated in the table below. In 2017, fresh whole fish fetched USD 4.5/kg, while in Japan fresh fillets fetched USD 11.6/kg, as indicated in Table 5-2 below.

Table 5-2: Global retail prices per a product (USD/kg)

	Frozen		Fresh	
Country/Region	**Whole fish**	**Fillet**	**Whole fish**	**Fillet**
USA	4.18	4.8	17	11
EU	0.75	6-131	4	5-6
Brazil	4.51, 2	101, 2	14	6-7
Singapore	1	4.51	4-51	6.9
Japan	1	6.95	4-5	11.62

Source: 1 - Globefish, 2017; 2 - Towers, 2017; 3 - Pers.Com., 2017; 4 - INFOFISH, 2015

From the table above, it is evident that Asia and European markets generally enjoy lower prices for tilapia in comparison to the USA markets, this could be attributed to shipping and import costs, as well as the demand for tilapia in the USA.

5.3.2. Regional and Local Markets

Tilapia is by far the favourite fish in most part of Africa, and is being sold as various products including:

1. **Fresh whole fish** – this is the most popular form of product and is most common at the source of the supplier (farms or fisheries sites) which can range from small sizes (150 grams) to 450 grams (average plate size) to a larger size of about 650 grams.

2. **Fresh or frozen fillet** – not that common but increasing in popularity. Mostly found at the retail outlets and upper markets restaurants. Increasingly these products can be found at retail outlets and through large commercial farms.

Source: INFOFISH, 2015

3. **Frozen whole fish** – Very common and mostly supplied though the importation channels (such as China and India). Typically sold at an average plate size fish.

Source: INFOFISH, 2015

4. **Dried/Salted**- Common product mostly in rural areas and is being offered by local traders. Asia markets often import to Africa countries, however local demand exceeds imports.

Source: INFOFISH, 2015

Prices of tilapia products varies by product type, size (normally traded as a 400-gram fish) and also varies from country to country, with countries such as Angola, DRC, Ghana, Nigeria, and Zambia recording more attractive prices and volumes. The regional retail prices can be summarised in the table below.

Table 5-3: Regional retail prices per a product (USD/kg)

	Frozen		Fresh	
Country/Region	**Whole fish**	**Fillet (per kg)**	**Whole fish**	**Fillet (per kg)**
Angola	15[4]	1.25	1-2	
DRC	5[4]	1.25	1	
Ghana	1.1	1.25	3-4[4]	
Malawi	1.5[3]	1.25	3[4]	
South Africa	3[3]	4.4	5[3]	3-4
Zambia	1[4]	1.25	3[4]	
Uganda	N/A	1.25	2.5[4]	
Nigeria	1.8	1.25	2.5[4]	

Source: [1] - Globefish, 2017; [2] - Towers, 2017; [3] - Pers.Com., 2017; [4] - INFOFISH, 2015

As seen in the table above, sourcing information such as fresh whole fish and fresh fillet prices is limited in Africa, as tilapia is often sold on local markets, and not at retail or formal outlets. From the data available, it is evident that South Africa (USD 3/kg) receives relatively low prices for frozen whole fish in comparison with the DRC (USD 5/kg) and Angola (USD 15/kg). In contrast, South Africa receives the highest price for fresh whole fish, indicating a similar trend to the USA markets, where fresh fish products dominate frozen products. Based on South African producer's experience, and ongoing research into the informal market for fish, it was found that if a rural rea or township has high representation of African diaspora communities, tilapia can be sold for R 12 per fish, which equates to an estimated R 50.00/kg and more. However, in a township or area where the African diaspora is small and widely spread, these prices are not likely to be achieved. Prices may range from R35-38.00/kg for 300-gram fish (Personal Communication, 2017).

5.4. Barriers to entry and limitations of the market

Barriers to entry, and market limitations are an important consideration when looking at the feasibility of a product. Various aspects such as market saturation, trade barriers, market competition and potential market restrictions are important for this market assessment.

5.4.1. Market Saturation

On the global export markets scene, both the EU and the USA markets have indicated saturation at some level, regarding the current supply of frozen fillet. This has already created some reaction from China, the key exporter of tilapia, as they have made efforts to develop the Chinese own local market as a possible market for its well-developed industry. With market saturation being experienced in major markets, the infant South Africa industry, will find it increasingly challenging to break into the global tilapia industry, specifically with frozen products. To overcome this barriers into the EU and the USA markets, South Africa would need to develop some unique value-added products that will suit the changing market preferences. South Africa should take a different approach to traditional frozen or fresh fillets to position themselves in a more competitive manner. To improve the current market position, the following approaches could be considered:

- Ready-made, prepared, and packaged meals offer high profit margins and meet consumer preference for convenience food,
- Innovative packaging such as resealable bags or 'cook-in-bag' options,
- New product forms such as smoked tilapia and sashimi grade tilapia will increase the high-end market demand,
- Fresh tilapia fillets offer a premium price over frozen, imported fillets,
- Changing market preference is increasing the interest and demand for organic, and sustainably produced fish products, and
- Sale of live fish at markets is increasing in popularity, specifically in countries with high migration rates from Asian countries. It should be noted this is only permitted for Mozambique tilapia, as the current Nile tilapia permits issued by the DEA prohibit the sales of live Nile tilapia (except for fingerlings) (Kaiser EDP and Enviro-fish Africa, 2011; Britz & Venter, 2016).

In order to address market saturation issues, and focus on processing opportunities, efforts to increase production and quality of tilapia being produced in South Africa is essential to ensure a constant supply is available.

5.4.2. Market Competition

The international export markets are currently dominated by the Asian producers who offer very attractive prices for frozen whole and process fillets. The South African industry would have difficultly competing with the current supply in terms of pricing, and volumes of fish required. Pricing plays a key role in the market, and with South African producers dealing with high production costs (electricity, feed, fuel, labour etc.), they require a selling price in order to cover their production costs and ensure their operation is profitable; thus, with higher selling prices required, the cheaper imports pose a major threat to local producers who are being out priced and out produced with their low production volumes.

Regional markets (Sub-Saharan) competition is mostly on the frozen imported products from Chinese, which dominate key markets already at attractive prices. Potential gap exists for fresh produce (mostly whole fish) provided the South African products could access these markets at affordable prices. Fresh supply is currently provided by local fisheries and small-scale (and a few commercial) farms. South African products are associated with high quality, which could be used as a competitive advantage in lucrative markets such as DRC (Personal Communication,2017).

5.4.3. Logistics Challenges

The existence of poor infrastructure (roads, cold chain systems for food preservation etc.) imposes serious limitations on market distribution in many African markets. A case in point is DRC market which offer attractive opportunities for trade provided supplier could access the various fish markets centres in the country (INFOFISH, 2015). Cold chain infrastructure including: storage facilities, frigerated track and trains, are lacking in the Sub-Sahara African markets. This create a critical bottle-neck in transportation of fresh goods from the expanding farms. In comparison to other African countries, South Africa has well developed transport and logistics networks, however the tilapia value-chain remains underdeveloped. The small-scale production that dominates the South African industry has not yielded the volumes to develop commercial scale agro-processing and logistics infrastructure (Kaiser EDP and Enviro-fish Africa, 2011). Locally, South Africa is well equipped from a cold chain and logistics perspective to supply the markets, however on a regional scale, exporting large quantities of tilapia out of the country could become challenging into the large African markets such as the DRC, where transportation is done by land, and where distribution into DRC is currently done through Zambian traders (Personal Communication,2017).

5.4.4. Trade Restrictions

According to (Kaiser EDP and Enviro-fish Africa, 2011), the size of the tilapia industry in South Africa has not warranted the certification of the sub-sector, however on a global scale this is problematic due to the popularity of tilapia internationally. The lack of certification in South Africa is becoming problematic with the Global Aquaculture Alliance (GAA), and the WWF aquaculture groups. Presently, no national monitoring system exists that is required to oversee Tilapia production and quality to ensure it complies with international standards, which is problematic for the South African export market, specifically if the USA or EU markets are the primary focus.

The USA and EU markets have stringent trade and marketing guidelines when it comes to food products, and livestock. Initial communication with South African official revealed that a possible ban exists on exporting to the EU market due to the lack of certification of the industry. Such limitation could be resolved with the introduction of certified labs to examine the required production test on each farm. As the demand for tilapia in Africa grows, import bans have been noticed in Nigeria and Ghana to protect and grow their local industries and reduce the high levels of dependence on imported products. Ghana declared a ban in 2008, which according to the FAO is still in place, while Nigeria is still focused primarily on local trade. Other trade challenges are associated with market requirements such as the ones in Malawi which have a preference to local species over the Nile or Mozambique tilapia.

Recent trends in 2017, is the development and outbreak of the Tilapia Lake Virus (TiLV), which although not a health concern for consumers, has the potential to destroy the tilapia population. The virus has been identified in Thailand, Ecuador, Egypt, Mozambique, Ghana, Israel, and Colombia. Countries importing Tilapia have been warned to implement strict risk reduction and management measures to reduce the risk of spreading the virus and affecting local Tilapia stocks. As a result of the virus outbreak, African countries such as Zambia are considering import bans to protect their local stocks (Mulenga, 2017).

5.4.5. Ease of Doing Business

Ease of doing business is a fundamental factor when assessing any export market. One specific issue is the cash economy in the continent which implies that trade could be risky as well as difficult due to currency conversion. Possible technological solution could be looked at such as PayPal electronic payment via cell phone network. Other markets such as in Angola, present another challenge associated with payment terms. Past experiences of South African farmers who exported into Angola proved to be problematic in terms of payment, due to the lack of hard currency in Angola and their inability to accommodate international trade needs. Technologically based platforms such as moWoza are providing payment gateway solutions and digitisation of the value-chain, however despite the improved technology, no solution for physical delivery challenges has been identified. (Valdi Pereira,2017).

5.4.6. Market immaturity

The South African local market is currently small in terms of tilapia production (Valdi Pereira,2017). (i.e.: estimated at about 1600 tons[7]). Fresh tilapia is an unknown product to the majority of South African consumers, who are accustomed to hake and/or other white fish products. An opportunity was identified in the past to offer tilapia as an alternative fish to the hake. The production scale is sufficient, and price is comparable to hake (IDC, 2015). However, the introduction of tilapia (with focus on fresh or frozen filet) will require intensive marketing and consumer education as well the development of production and processing capacity at the right scale.

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[7] *As per the stakeholder, 1600 tons reflects a market where potential buyers are willing to pay prices in the region of R 38.00/kg making it feasible for a volume producer. The market is definitely bigger than this but the willingness of buyers to pay a higher price is currently undetermined.*

6. Nile and Mozambique Tilapia: SWOT analysis and Mitigation measures

6.1. SWOT Analysis

Table 6-1 below presents the strength, weaknesses, opportunities, and the threats faced by the Nile and Mozambique Tilapia industry in South Africa.

Table 6-1: Nile and Mozambique Tilapia SWOT Analysis

Strengths	Weaknesses
• Diversified products: fresh, frozen, smoked, canned, paté, leather, etc. • Popular fish amongst consumers • Local and export opportunities • Fish seen as a healthy source of protein • Year-round production is possible • Creates jobs and learning opportunities • Fast growing (Nile tilapia) • Industry has experienced growth over last few years in South Africa	• Excess food, faeces, cage material, and antibiotics can pollute the water source • Lack of recent production data available • Limited expertise and professionals • High feed cost and low-quality feed • Complexity in terms of marketing and operations and post production technologies, • High capital cost for start-up and lack of funder appetite
Opportunities	**Threats**
• Good infrastructure for most of South Africa • Good export market channels • Linkages with tourism • Growing demand for an affordable protein source • Shortage in traditional fisheries products • Investment opportunities	• Inability to acquire permits for production, • Shortage of extension services, technical skills, and support • Complex resource-based legislation (specifically water & land) • Climate variability in the country • Lack of the right technology and high technology costs • Shortage of suitable freshwater resources • Parasites & disease outbreak

The generic economic model considered some key weaknesses and threats that would impact on profitability. The model assists with developing a risk profile for producers which is used to determine interest rates and loan repayments based on education levels and skills, and access to land, infrastructure, and facilities. Factors such as permit costs and veterinary costs are built into the model to mitigate the potential disease outbreak threat.

6.2. Mitigation Measures

The mitigation measures identified in the table below aim to address the threats and weaknesses identified in the SWOT analysis discussed above. It is essential for Nile and Mozambique tilapia producers to take note of the potential risks and weaknesses identified to ensure they can implement mitigation measures and understand the challenges they may face.

Table 6-2: Nile and Mozambique Tilapia Mitigation Measures

Risks Identified	Mitigation Measures
I. Water Pollution	• Tilapia producers should implement waste water management practices and comply with legislation. • Strategic guidelines as to waste water disposal for tilapia production should be developed.
II. Lack of Production Data	• Encourage and build a working relationship between producers and government departments to ensure co-operation and sharing of data • Annual reporting of all producers should be encouraged and supported.
III. Lack of skills, expertise & sharing of knowledge	• Encourage engagements between industry experts & local producers. • Equip extension officers to assist tilapia producers. • Develop mentorship programmes and workshops.
IV. Feed quality & costs	• Research and development should be focused on developing high quality, locally produced feeds at affordable prices. • Producers in outlying areas should be identified to assess the need for fish feed processing facilities in provinces such as Mpumalanga or Limpopo.
V. Post Production challenges	• Marketing campaign to promote and increase awareness around tilapia. • Facilitate discussions between producers and retail outlets to establish off-take agreements.
VI. High Capital & operating costs	• Research and development should be focused on developing reducing operating costs. • Pilot projects to test various alternative systems that could reduce capital expenditure.
VII. Lack of funder interest	• Focus on growth and development of the industry to increase the “attractiveness” for investors. • Develop strategic guidelines to assist producers in establishing well design and planned aquaculture operations. • Develop a platform that facilitates communication between producers, funding institutions or investors and government.
VIII. Permits & regulations	• Streamline the permit and regulatory application process for producers. • Improved communication between regulatory bodies and producers to ensure transparency and co-operation.
IX. High technology costs	• Research and development should focus on producing system technology locally, so it is relevant and affordable for South Africa producers.
X. Parasite & disease outbreaks	• Develop biosecurity and disease control guidelines, included in the Strategic guidelines for tilapia production. • Implement regulatory checks and site visits to ensure operations comply with biosecurity measures.

7. Nile and Mozambique Tilapia Technical Assessment

The technical assessment below provides a summary of the assumptions used within the economic model for both Nile and Mozambique tilapia, as well as data presented in the species overview and biological characteristics. The technical assessment covers the following information:

- Water conditions,
- Broodstock/Breeding,
- Genetic selection,
- Hatchery/fry production,
- Production performance, and
- Additional information.

Industry experts, stakeholders and relevant literature sources provided the technical information below. This information may be subject to change.

Table 7-1: Tilapia Technical Assessment

Latin name	*Oreochromis Mozambique; Oreochromis niloticus*
Common name	• Mozambique tilapia • Nile tilapia
Natural range	Tropical and subtropical Africa, Southern Africa from lower Zambezi to Brak River, and Limpopo system. Widely introduced to other parts of Africa, Europe, and Asia.
Water Conditions	
Salinity	Fresh and brackish water. Salinity should be lower than 10 ppt.
pH	Tolerable range: 5 -10 Optimal production range: 6 -9
Nitrites	Less than 5mg/l NO_2-N
Ammonia	Less than 2 mg/l NH_3-N
Oxygen Requirements	Between 4 and 6 mg/L
Temperature	28 -36°C
Broodstock/breeding	
Spawning	Sexual maturity in ponds is reached at an age of five to six months. Spawning begins when the water temperature reaches 24°C. Breeding is conducted in ponds, tanks, or cages. The stocking ratio for females to males is 1-4:1 with 2 or 3:1 being the most common. The brood fish stocking rate is variable, ranging from 0.3-0.7 kg/m^2 in small tanks to 0.2-0.3 kg/m^2 in ponds.
(Natural/induced)	Tilapias are asynchronous breeders. Hormones are not used to induce spawning, which occurs throughout the year in the tropics and during the warm season in the subtropics.
Egg size	A 100 g female will produce about 100 eggs per spawn, while a female weighing 600-1 000 g can produce 1 000 to 1 500 eggs. The female incubates the eggs in her mouth and broods the fry after hatching until the yolk sac is absorbed.
Genetic selection	
Mono sex	There are two methods for producing all-male Tilapia fingerling batches: 1) Sex reversal of fry using a synthetic male androgen (17-alpha methyltestosterone) administered in feed for 28 days post-hatch 2) Spawning female Tilapia with Tilapia males that have two Y chromosomes.
Hatchery/fry production	
Hatchery system	Swim-up fry are generally <9 mm. A powdered commercial feed or powdered

Latin name	***Oreochromis Mozambique; Oreochromis niloticus***
	fish meal, containing >40 percent protein, fry are stocked at 3 000 to 4 000/m² in ponds or tanks with water exchange. Stocking densities as high as 20 000/m² have been used if good water quality can be maintained. Reversed fingerlings are stocked at approximately 20-25 fish/m² in small ponds and cultured for two to three months to an average size of 30-40 g.
First feed requirement	They can be given commercial dry feeds, size 00 or 0, after they have absorbed their yolk sacs. The fine powder form allows some of the feed to float, encouraging surface feeding. Powdered commercial feed or powdered fish meal, containing >40 percent protein. An initial feeding rate of 40% body weight per day is gradually decreased over the course of four weeks.
Hatchery survival	80% egg survival.
Production performance	
Typical FCR	Tank and cage cultured Tilapia can have very efficient feed conversion ratios (FCR) of 1.2:1 to 1.6:1.
Feed requirement	I. **RAS, Aquaponics & Cage culture** • Month 1 feed is calculated on 40% of the body mass • Month 2 feed is based on 10% of body mass • Month 3+ is based on 1.5% body weight. II. **Pond Culture** • Only from Month 3+ is feed required in the ponds at approximately 1% of body mass. III. **Ranching, Flow-through & Raceways** • Other systems require further testing and research to understand feed requirements and ratios
Typical survival rate	• **Mozambique** – 85% • **Nile** – 95%
Typical growth rate	• **Mozambique** – Over 14 months experiences a growth rate of 21% • **Nile** – over 9 months experiences a 33% growth rate
Production cycle (weight/months)	• **Mozambique –** 475 grams after 14 months • **Nile –** 500 grams after 9 months
Stocking densities	• **RAS/Aquaponics:** 20 kg/m³ • **Cage culture:** 53 kg/m³ • **Pond:** 1.5 kg/m²
Additional Information	
Research & Development and recent innovations	Some current trends include: I. The development of new faster growing strains through selective breeding techniques. II. Breeding procedures to produce genetically male Tilapia (GMT) without direct hormone use. III. Pond polyculture systems. IV. Intensive cost-effective recirculation systems V. Use of mixed cell raceway systems.
Invasive Status	• **Nile –** Classified as Alien Invasive Species. Included in NEMBA, however permits can be issued for production. • **Mozambique –** Indigenous species to South Africa. Not classified as invasive

Latin name	*Oreochromis Mozambique; Oreochromis niloticus*
Permits required	I. **Nile** - **Tons <20**: National Permit with Risk Assessment required - **Tons <200:** National Permit and with Risk Assessment PLUS Basic Assessment required - Provincial permits apply specifically in KwaZulu Natal, Mpumalanga and Limpopo[8] II. **Mozambique** - **Tons <20**: Provincial Permit - **Tons <200:** Provincial Permit and Basic Assessment required - Provincial permits apply specifically in KwaZulu Natal, Mpumalanga and Limpopo[9]

From the technical assessment above, it can be said that Nile tilapia has an added advantage in terms of its growth rates particularly due to genetic selection and breeding programmes, marketable size, and survival rate under aquaculture systems, making it a more popular choice for producers. However, the permits and regulations linked to Nile tilapia due to its classification as an alien invasive species makes approval and permits for production somewhat challenging. Research and development is underway to increase the growth rates of Mozambique tilapia, which in the long term may make it more popular for production in South Africa, as well as the indigenous status of Mozambique tilapia, which makes permit applications easier for producers to attain. The ability of Mozambique tilapia to withstand salinity, could see the culturing of Mozambique tilapia in salt water-based aquaculture systems, this can be encouraged by conducting test or pilot projects to determine the optimal salinity and the growth and survival rates under these conditions.

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[8] *Permits and applications are currently under review by DAFF*

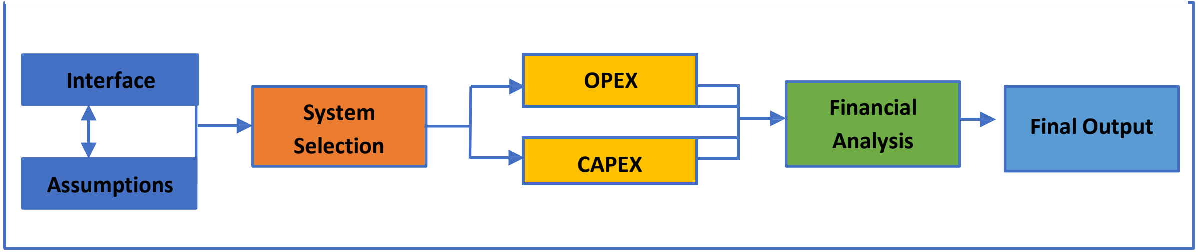
[9] *Permits and applications are currently under review by DAFF*

8. Nile Tilapia Financial Analysis

8.1. Introduction

The generic economic model provides users with the opportunity to individual producer data, proposed production volumes and scales and financial data. Through the model, the users will receive financial outputs which include capital and operational costs and financial indicators which will guide the user in determining whether the proposed aquaculture project is feasible, and a viable investment opportunity. A high-level overview of the model process can be seen in the figure below.

Figure 8-1: Generic Economic Model Overview



Source: Urban-Econ,2018

The generic economic model can be customised to provide results for individual producers based on selections made with regard to the location of the aquaculture operation (at a provincial level), type of operation (start-up or existing), the scale of operation, type of production system, size and pricing of the Nile tilapia, education level and type of financing that will be used (equity or debt/equity).

8.2. Key Production Assumptions

The generic economic model for Nile tilapia was developed using data from various information sources, consultations with various stakeholders and industry experts, and through inputs gathered at two peer-review workshops conducted.

8.2.1. Production Assumptions

To develop the generic economic model, specific production assumptions for Nile tilapia were identified and utilised. Some key assumptions used can be seen in Table 8-1 below.

Table 8-1: Nile tilapia Production Assumptions

Tilapia fingerlings	R 2.00 (*50 g fingerling)*
Maximum Production Cycle Length	9 months (500 grams)
Survival Rate	85 %
Mortality Rate (9 months)	15 %
Average Feed price	R 12/kg
Stocking Density	• **RAS/Aquaponics:** 20 kg/m^3 • **Cage culture:** 53 kg/m^3 • **Pond:** 1.5 kg/m^2

Industry experts recommended the assumptions seen above, however, they may differ from farm to farm. Prices are based on 2017/2018 prices and are subject to change over time. Producers should be encouraged to establish relationships with suppliers to benefit from bulk prices, specifically at larger tonnages.

It is important to note that the results below are unique for each system and based on the results obtained from the generic economic model. The average selling price identified is based on the stakeholder consultations and may not be identical to current market prices. When considering Nile tilapia production, it is essential to consider the target market, demand, and a realistic selling price to ensure the project is sustainable.

The land size identified above is calculated based on the minimum infrastructure footprints. As each aquaculture operation will differ according to layout, design, and infrastructure requirements, the land size should be used as a guideline for the minimum size property.

The generic economic model accounts only for the sale of whole tilapia, sold directly from the farm to either a third-party processors, retail markets or directly to consumers looking to purchase whole tilapia. Should processing be required on a farm, additional capital will be required.

8.2.2. Capital Expenditure

The capital expenditure costs for Nile tilapia production focused on the establishment of the potential production systems identified for Nile tilapia production in South Africa. The capital expenditure is determined by the scale of production, and the selected production cycle length. Some of the key factors to note include the following:

a. **Pre-development costs** for construction phase, concept design, specialist consultations, town planning alignment (zoning, rezoning etc.), and development of bulk infrastructure (roads, installation of electricity to the site, bulk water services etc.) were excluded from the model as this is site specific and not suitable to model at a provincial level,
b. **Land costs** were included should an individual/business not have an existing farm. Based on average farm prices for 2017/2018, a per hectare (ha) rate of R 246 346 was used.
c. **Services** such as the costs of water and electricity were included in the model, and vary between the nine provinces,
d. **Buildings** such as storerooms, offices, cold storage, and a feed room were considered,
e. **Aquaculture system** costs focused on the development of the five production systems,
f. **A storage dam** was included in the capital expenditure costs for selected production systems.
g. **Infrastructure costs** are calculated as a once-off, lump sum amount to be spent in year one, however a producer can choose to phase in production which would spilt the costs up depending on how the production is phased in.

8.2.3. Operational Expenditure

Operational expenditure, or working capital was determined by looking at the variable costs of production, and fixed costs. Costs can be divided into fixed and variable costs. **Variable costs** include fingerlings, fertilisers (where required), feed, transport, and water costs. It should be noted that it is was assumed that aquaculture producers in South Africa are currently not charged for water unless using municipal water sources (DAFF,2018).

Fixed Costs include costs such as salaries, insurance, electricity, legal/licensing costs, veterinary services, and general expenses (telephone, electricity, health and safety apparel, stationery etc.). Reserve and unforeseen costs have also been included (calculated at 2% of the variable cost total).

8.2.4. Scale of production

From the generic economic model, two production volumes were identified. Firstly, the minimum production volume which indicates at what tonnage a producer would first be profitable. Secondly, the optimal production tonnage was identified, which indicates where the optimal return on investment and profitability is achieved.

8.2.1. Market Information

Tilapia market information was based on industry experts and research conducted. The average farm gate price for Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa, however through the results obtained by the generic economic model, specific price ranges have been identified for each production system, thus pricing is specific to the production system selected and is discussed in more detail in the sections below.

8.3. Nile Tilapia: Financial Overview

Using the generic economic models and the assumptions listed in Table 8-2 below, a financial analysis was conducted for Nile tilapia.

Table 8-2: Nile tilapia Generic Economic Model Selection Inputs

Province	Limpopo
Market	Local
Operational Status	Start-up farmer with no existing farm, facilities, or infrastructure
Skills Level	Formal education (certificate/diploma)
Payback Period	20 years
Financing Option	Debt/Equity with an investor (surety)
Debt Percentage	20%
Production Cycle – Nile tilapia	465 grams (8 months)
Additional Information	• The models exclude the construction phase. The models consider from when production starts • The model excludes consultancy, contactors, and specialised service provider fees, with the exception of veterinary services.

The four production systems considered were the Recirculating Aquaculture Systems (RAS), Pond Systems, Cage Culture and Aquaponics. Systems such as ranching, flow-throughs, and raceways were not included in the economic model as these systems were not deemed viable as previously discussed. Each potential production system requires specific infrastructure and facilities and has specific production parameters, which is discussed in more detail below.

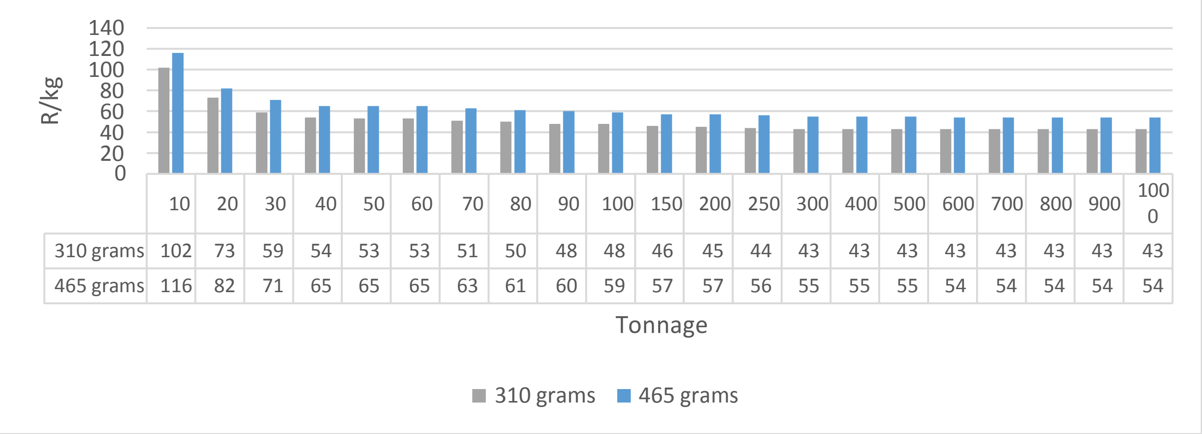
8.3.1. Recirculating Aquaculture Systems

A RAS is known for high operating costs which can be attributed to the high electricity usage for pumping and general operation of the system, as well as feed costs associated with artificial feed sources being the primary food source. With regards to infrastructure costs, RAS require temperature control measures and heating equipment, as well as tunnel system to assist with reducing electricity consumption and maintaining a constant water temperature. Based on the assumptions presented in Table 8-2 above, the results obtained from the generic economic model for the RAS are discussed in the section below

8.3.1.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa, however based on the generic economic model results, it is evident that at these prices, it would not be profitable for a start-up producer to produce Nile tilapia. Figure 8-2 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-2: Nile Tilapia: RAS Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
▨ 310 grams	102	73	59	54	53	53	51	50	48	48	46	45	44	43	43	43	43	43	43	43	43
■ 465 grams	116	82	71	65	65	65	63	61	60	59	57	57	56	55	55	55	54	54	54	54	54

The size of the Nile tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **310-gram fish:** R 53/kilogram
- **465-gram fish:** R 65/kilogram

For the purpose of this financial analysis, a 465-gram fish has been selected, and sold at the average price of R 62 per kilogram identified from the graph above. The stakeholder consultations identified a local farm gate price of R40/kg. however, markets are not always meeting this price, thus affecting the production volumes and profitability of tilapia farms in South Africa.

8.3.1.2. Capital Expenditure

Table 8-3 below provides a summary of the infrastructure and built environment costs required to establish a RAS for Nile tilapia production.

Table 8-3: RAS Capital Expenditure

Production Scale	Min Profitable 73 tons	Optimal 525 tons
Purchasing Land	R 715 941	R 3 482 642
Infrastructure (Buildings & Tunnels)	R 3 181 000	R 15 351 600
RAS Infrastructure	R 3 478 562	R 23 130 699
Additional equipment	R 74 300	R 494 838
Total Capital Expenditure	**R 7 763 805**	**R 57 811 381**

8.3.1.3. Operational Expenditure

Table 8-4 below provides a summary of the operational costs required for Nile tilapia production. The operational expenditure is shown for the first year of operation.

Table 8-4: Total RAS Operational Expenditure for Nile tilapia Production (Year 1)

Production Scale	Min Profitable 73 tons	Optimal 525 tons
Variable costs	**R 1 982 586**	**R 14 245 321**
Tilapia fingerlings	*R 362 282*	*R 2 605 49*
Feed	*R 1 497 753*	*R 10 771 512*
Water Quality Consumables	*R 10 950*	*R 78 750*
Fixed Costs	**R 1 328 574**	**R 4 826 835**
Total Operational Costs	**R 3 311 160**	**R 19 072 156**

Based on the table above, it is evident that feed costs account for an estimated 20 to 30% of the total operational expenditure (depending on the tonnage). Currently in South Africa, fish feed is manufactured by one or two key commercial feed producers, alternatively producers make up their own feed mixes. Feed is a crucial aspect of an aquaculture operation as it can impact on the growth rates, health and quality of the fish produced.

8.3.1.4. RAS Financial Overview

Table 8-5 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-5: Recirculating Aquaculture System Financial Overview

Production Scale	Min Profitable 73 tons	Optimal 525 tons
Financial Indicators		
Total Capital Expenditure	R 9 689 071.24	R 68 182 210.83
Loan Amount – Working Capital	R 1 925 265.82	R 10 370 829.33
Loam Amount - Infrastructure	R 7 763 805.42	R 57 811 381.50
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.02	2.86
Internal Rate Return (IRR)	7%	26%
Net Present Value over 10 years	R 9 922 775	R 195 075 032
Pay-back period (year)	20	20
Years until Profitable	9	2
Production Indicators		
Farm Size (hectares)	2.9 hectares	14 hectares
Number of fingerlings required	15 095	108 561
Number of employees (Year 1)	8	30

The minimum profitable tonnage was identified at 73 tons per annum when selling the fish at R 62/kg. It is estimated that R 9 689 071 is required to establish the production system and cover the working capital costs for eight (8) months. To establish the system for 525 tons, it is estimated that R 68 182 210 is required. A key factor is the operational costs (specifically feed) and the infrastructure required for the RAS.

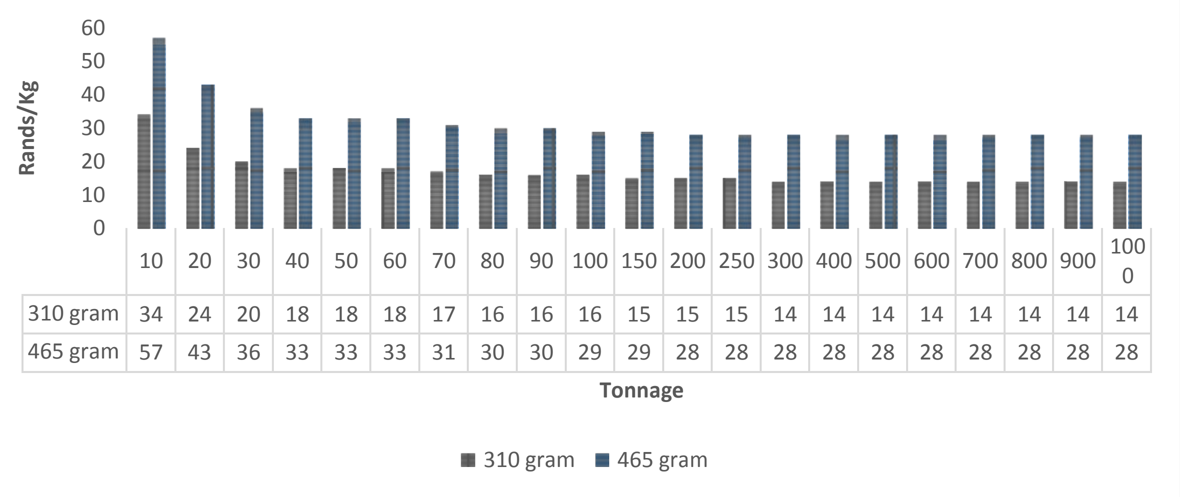
8.3.2. Pond Systems

Based on the assumptions presented in Table 8-2, the following results were obtained from the generic economic model. It should be noted, that although pond culture has been included, Nile tilapia is not recommended for pond culture due to its invasive species status.

8.3.2.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa. Figure 8-3 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-3: Nile Tilapia: Pond Culture Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
310 gram	34	24	20	18	18	18	17	16	16	16	15	15	15	14	14	14	14	14	14	14	14
465 gram	57	43	36	33	33	33	31	30	30	29	29	28	28	28	28	28	28	28	28	28	28

The size of the Nile tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **310-gram fish:** R18/kilogram
- **465-gram fish:** R 33/kilogram

For the purpose of this financial analysis, a 465-gram fish has been selected, and sold at the average price of R 32 per kilogram identified from the graph above. The stakeholder consultations identified a local farm gate price of R40/kg. however, markets are not always meeting this price, thus affecting the production volumes and profitability of tilapia farms in South Africa.

8.3.2.2. Capital Expenditure

Table 8-6 below provides a summary of the infrastructure and built environment costs required to utilise pond culture for Nile tilapia production.

Table 8-6: Pond Culture Capital Expenditure

Production Scale	Min Profitable 44 tons	Optimal 398 tons
Purchase Land	R 2 061 793	R 2 131 650
Infrastructure (Buildings & Storage Dam)	R 1 248 850	R 13 889 653
Pond Infrastructure	R 3 792 860	R 29 057 620
Additional equipment	R 224 021	R 902 232
Total Capital Expenditure	**R 7 405 524**	**R 53 401 875**

8.3.3. Operational Expenditure

Table 8-7 below provides a summary of the operational costs required for Nile tilapia production. The operational expenditure is shown for the first year of operation.

Table 8-7: Pond Culture Operational Expenditure for Nile tilapia Production (Year 1)

Production Scale	Min Profitable 44 tons	Optimal 398 tons
Variable costs	**R 1 311 817**	**R 11 689 151**
Tilapia fingerlings	*R 218 362*	*R 1 975 186*
Fertiliser	*R 116 000*	*R 889 333*
Feed	*R 902 755*	*R 8 165 832*
Consumables – water quality	*R 6 600*	*R 59 700*
Fixed Costs	**R 948 866**	**R 3 568 527**
Total Operational Costs	**R 2 260 684**	**R 15 257 678**

Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts. In addition to bulk feed prices, producers should identify bulk fertiliser and equipment suppliers to ensure producers can achieve economies of scale.

8.3.3.1. Pond Culture Financial Overview

Table 8-8 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-8: Pond Culture Financial Overview

Production Scale	Min Profitable 44 tons	Optimal 398 tons
	Financial Indicators	
Total Capital Expenditure	R 8 765 732.30	R 62 004 513.29
Loan Amount – Working Capital	R 1 360 208.06	R 8 602 637.78
Loam Amount - Infrastructure	R 7 405 524.25	R 53 401 875.51
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.09	3.56
Internal Rate Return (IRR)	8%	31%
Net Present Value over 10 years	R 9 563 783.72	R 220 677 939.55
Pay-back period (year)	20	20
Years until profitable	7	2
	Production Indicators	
Farm Size (hectares)	8 hectares	56 hectares

Production Scale	Min Profitable 44 tons	Optimal 398 tons
Number of fingerlings required	9 098	82 299
Number of employees (Year 1)	4	24

The minimum profitable tonnage was identified at 44 tons per annum when selling the fish at R 32/kg, which is lower than the price identified by stakeholders of R40/kg. It is important to consider the costs associated with a pond system, with an estimated R 8 765 732 required to support 44 tons of production per annum. To support 398 tons per annum, capital investment of R 62 004 513 is required.

8.3.4. Aquaponics Systems

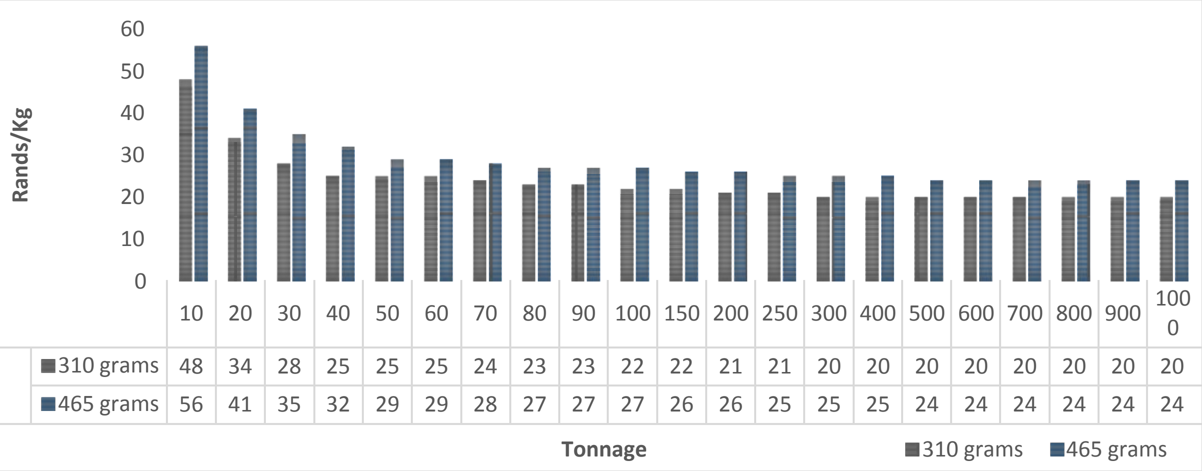
Aquaponics is one of the more profitable production system, specifically as producers benefit from two income streams (vegetables and fish). The generic economic model is based on the production of leafy green vegetables (lettuce, spinach, pak choi and basil) as these are the easiest to grow in comparison to vegetables such as tomatoes, carrots etc. It is assumed that the plant production will be phased in over the first year.

It should be noted that the analysis blow is conducted using the assumption that 20% of the RAS water will be reused, however, depending on the scale of the operation this can be increased or decreased to suit a project.

8.3.4.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa, however based on the generic economic model results, it is evident that when producing in an aquaponic system, producers could lower their selling prices and remain profitable, this due to the double income streams generated from the fish and vegetables being produced. Figure 8-4 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 8-4: Nile Tilapia: Aquaponics Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
■310 grams	48	34	28	25	25	25	24	23	23	22	22	21	21	20	20	20	20	20	20	20	20
■465 grams	56	41	35	32	29	29	28	27	27	27	26	26	25	25	25	24	24	24	24	24	24

The size of the Nile tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **310-gram fish:** R25/kilogram
- **465-gram fish:** R 29/kilogram

For the purpose of this financial analysis, a 465-gram fish has been selected, and sold at the average price of R 29 per kilogram identified from the graph above.

8.3.4.2. Capital Expenditure

Table 8-9 below provides a summary of the infrastructure and built environment costs required to utilise aquaponics for Nile tilapia production in South Africa.

Table 8-9: Aquaponics Capital Expenditure

Production Scale	Min Profitable 47 tons	Optimal 786 tons
Purchase Land	R 512 179	R 4 407 034
Infrastructure (Buildings & Tunnels)	R 3 892 845	R 44 611 615
Aquaponics system	R 3 943 127	R 60 237 666
Additional equipment	R 314 761	R 2 355 542
Total Capital Expenditure	**R 9 082 890**	**R 118 812 528**

8.3.4.3. Operational Expenditure

Table 8-10 below provides a summary of the operational costs required for Nile tilapia production. The operational expenditure is shown for the first year of operation.

Table 8-10: Total Aquaponics Operational Expenditure for Nile tilapia Production (Year 1)

Production Scale	Min Profitable 47 tons	Optimal 786 tons
Variable costs	**R 1 405 289**	**R 23 401 726**
Tilapia fingerlings	*R 233 250*	*R 3 900 744*
Feed	*R 964 306*	*R 16 126 492*
Consumables – water quality	*R 7 050*	*R 117 900*
Hydroponic Net Pots (5% annual replacement)	*R 2 026*	*R 33 894*
Additional (chemicals/nutrients etc)	*R 4 449*	*R 7 920*
Seedlings	*R 121 606*	*R 2 033 675*
Fixed Costs	**R 1 061 514**	**R 7 606 478**
Total Operational Costs	**R 2 466 804**	**R 31 008 204**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of an aquaponics operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts. In addition to bulk feed prices, producers should identify bulk seedling suppliers, or alternatively investigate the feasibility of establishing their own growing facility for seedlings. Packaging and labelling required for the vegetables has not be included in the costing above, and should be considered by producers, specifically based on the target market requirements.

8.3.4.4. Aquaponics Financial Overview

Table 8-11 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-11: Aquaponics Financial Overview

Production Scale	Min Profitable 47 tons	Optimal 786 tons
Financial Indicators		
Total Capital Expenditure	R 10 569 176.04	R 135 230 260.03
Loan Amount – Working Capital	R 1 486 285.75	R 17 047 731.79
Loam Amount - Infrastructure	R 9 082 890.29	R 118 182 528.24
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.01	3.39
Internal Rate Return (IRR)	7%	30%
Net Present Value over 10 years	R 10 680 380.55	R 458 872 234.34
Pay-back period (year)	20	20
Years until profitable	8	2
Production Indicators		
Farm Size (hectares)	2 hectares	21 hectares
Number of fingerlings required	9 719	162 531
Number of employees (Year 1)	6	52

The minimum profitable tonnage was identified at 64 tons per annum when selling the fish at R 29/kg, which is below the typical farm-gate price of R 30 -40 /kg. The aquaponics system in the generic economic model makes use of the same concrete/cement tanks utilised for the flow-through system, however using the RAS technology. It is estimated that a capital expenditure of R 10 569 176 is required to support 47 tons per annum, and R 135 230 260 to support the optimal annual production of 786 tons. The costs associated with establishing and operating an aquaponics system are predominantly linked to the infrastructure development and operational costs of feed, and seedlings.

8.3.5. Cage Culture

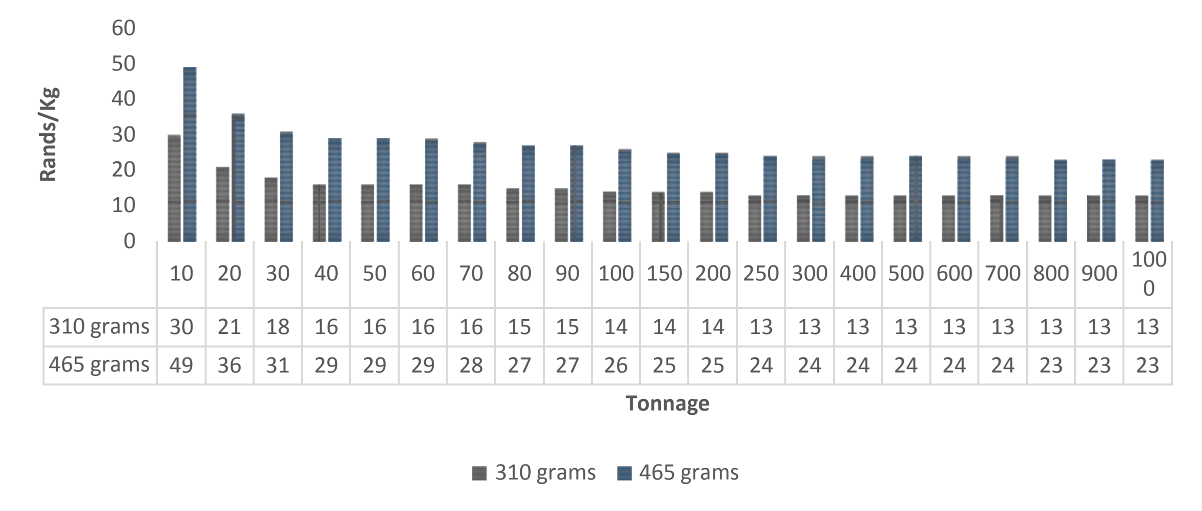
Cage culture was considered in Limpopo due to the climatic conditions which are suited to Nile tilapia production. Cage culture differs from other production systems as it offers producers lower operational expenses (electricity etc) as well as lower infrastructure development costs. There is a challenging when identifying or locating suitable bodies of water that can support the proposed carrying capacity of a system.

8.3.5.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa. Figure 8-5 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

The size of the Nile tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes.

Figure 8-5: Nile Tilapia Cage Culture Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
310 grams	30	21	18	16	16	16	16	15	15	14	14	14	13	13	13	13	13	13	13	13	13
465 grams	49	36	31	29	29	29	28	27	27	26	25	25	24	24	24	24	24	24	23	23	23

There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **310-gram fish:** R16/kilogram
- **465-gram fish:** R 29/kilogram

For the purpose of this financial analysis, a 465-gram fish has been selected, and sold at the average price of R 27 per kilogram identified from the graph above.

8.3.5.2. Capital Expenditure

Table 8-12 below provides a summary of the infrastructure and built environment costs required to utilise cage culture for Nile tilapia production in South Africa.

Table 8-12: Cage Culture Capital Expenditure

Production Scale	Min Profitable 75 tons	Optimal 786 tons
Purchase Land	R 251 519	R 258 540
Infrastructure (Buildings)	R 1 267 000	R 3 168 000
Cage Culture system	R 176 729	R 2 304 549
Additional equipment	R 357 000	R 977 546
Total Capital Expenditure	**R 2 066 248**	**R 6 741 635**

8.3.5.3. Operational Expenditure

Table 8-13 below provides a summary of the operational costs required for Nile tilapia production. The operational expenditure is shown for the first year of operation.

Table 8-13: Total Cage Culture Operational Expenditure for Nile tilapia Production (Year 1)

Production Scale	Min Profitable 75 tons	Optimal 786 tons
Variable costs	**R 2 111 845**	**R 27 513 186**

Production Scale	Min Profitable 75 tons	Optimal 786 tons
Tilapia fingerlings	*R 372 208*	*R 4 853 598*
Feed	*R 1 538 787*	*R 20 065 788*
Consumables – water quality	*R 11 250*	*R 146 700*
Fixed Costs	**R 1 228 917**	**R 5 944 704**
Total Operational Costs	**R 3 340 763**	**R 33 457 890**

8.3.5.4. Cage Culture Financial Overview

Table 8-14 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 8-14: Cage Culture Financial Overview

Production Scale	Min Profitable 75 tons	Optimal 786 tons
Financial Indicators		
Total Capital Expenditure	R 3 967 187.45	R 24 066 445.02
Loan Amount – Working Capital	R 1 900 938.8	R 17 324 809.70
Loam Amount - Infrastructure	R 2 066 248.65	R 6 741 635.31
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.06	18.18
Internal Rate Return (IRR)	8%	88%
Net Present Value over 10 years	R 2 233 740.91	R 329 525 608.68
Pay-back period (year)	20	20
Years until profitable	6	2
Production Indicators		
Farm Size (hectares)	1 hectare	1 hectare
Number of fingerlings required	15 509	202 233
Number of employees (Year 1)	8	33

The minimum profitable tonnage was identified at 75 tons per annum when selling the fish at R 27/kg, which is lower than the typical farm-gate price of R 30-40/kg. It is important to consider the costs associated with cage culture, with an estimated R 3 967 187 required to support the minimum profitable tonnage, while the optimal production level of 786 tons per annum would require a capital investment of R 24 066 445 for a start-up producer. The costs associated with establishing and operating a cage culture operation are far lower than any of the other systems, which is linked to less infrastructure requirements, much lower day-to-day operational costs as well as a reduced demand for land, electricity, and additional expenses such as fertilisers or tunnels.

8.3.6. Nile Tilapia Financial Analysis Summary

Based on the financial analysis conducted for each of the four (4) production system above, it is evident that each system offers advantages and disadvantages for producers. The table below provides a high-level summary of the capital expenditure required for the minimum profitable tonnage, and the estimated return on investment.

Table 8-15: Summary: Production Systems Financial Overview

	RAS	Pond	Cage	Aquaponics
Tonnage	73	44	75	47

	RAS	Pond	Cage	Aquaponics
Average Selling Price	R 62/kg	R 32/kg	R 27/kg	R 29/kg
Capital Expenditure	R 9 689 071	R 8 765 732	R 3 967 187	R 10 569 176
IRR	7%	8%	8%	7%

From a financial aspect, it is clear that cage culture requires the lowest capital expenditure to establish at the minimum profitable tonnage (R 3 967 187) and also offers producers the lowest operational costs. However, although economically attractive the system comes with several challenges, namely identifying and securing a suitable body of water, as well as maintaining the cage culture system to ensure the water body conditions are maintained and does not negatively impact the surrounding natural environment.

The RAS and aquaponics require the highest capital expenditure and also have the highest operational costs due to the electricity, pumping, and infrastructure requirements. The RAS requires an average farm gate price of R 62/kg when producing the minimum profitable of 73 tons per annum. Aquaponics offers producers two income streams and a more stable income from month one of production. Pond culture systems offer an affordable solution for producers with much lower operational expenses, and also the ideal culturing system for the Nile tilapia, however, it should be noted that Nile tilapia is not permitted to be cultured in ponds due to its AIS classification.

8.3.7. Nile Tilapia Cost-Benefit Analysis

Table 8-16 below shows a high-level cost benefit analysis for Nile tilapia, based on the profitability index (PI) which is used as the cost benefit ratio. The analysis considers the four (4) production systems, at the minimum profitable tonnage and optimal production volumes as identified in the section above.

Table 8-16: Nile Tilapia: Cost Benefit Analysis

	RAS	Pond	Cage	Aquaponics
Minimum Profitable Tonnage				
Market price (R/kg)	R 62/kg	R 32/kg	R 27/kg	R 29/kg
Tons produced/annum	73	44	75	47
Profitability Index (PI)	1.02	1.09	1.06	1.01
Internal Rate of Return (IRR)	7%	8%	8%	7%
Employees required (Year 1)	8	4	8	6
Optimal Tonnage				
Market price (R/kg)	R 62/kg	R 32/kg	R 27/kg	R 29/kg
Tons produced/annum	525	398	978	786
Profitability Index (PI)	3.72	3.56	18.18	3.39
Internal Rate of Return (IRR)	32%	31%	88%	30%
Employees required (Year 1)	30	24	33	52

Based on the table above, when considering the minimum profitable tonnage identified in the various systems, aquaponics is profitable at 47 tons per annum when selling at the average price of R 29/kg identified in the generic economic. The low average selling price can be attributed to the two income streams associated with aquaponics. Should a producer grow the full vegetable crop from month one (1), and not phase in the production, this system will be highly profitable at lower tonnages. The selling price of Nile tilapia plays a major role in the profitability of an operation, which is illustrated above. Systems such as the RAS have higher operating costs thus require higher selling prices in order to be profitable.

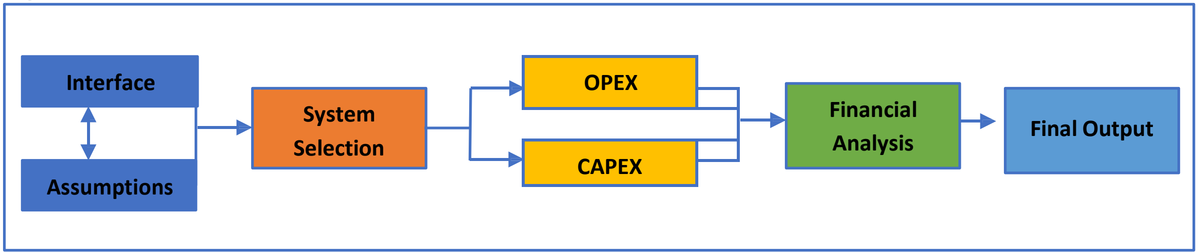
Each system offers a number of employment opportunities, specifically at the higher tonnages, where more specialised and skilled employees can be used as the operation will be able to cover their salaries. At the lower tonnages, it is recommended that labour costs are kept to a minimum to ensure the operation is profitable, thus all systems offer between four (4) and eight (8) jobs in year one of operation. The most labour-intensive systems at the higher tonnages, as seen in the table above include aquaponics (52), followed by cage culture (33) and RAS (30).

9. Mozambique Tilapia Financial Analysis

9.1. Introduction

The generic economic model provides users with the opportunity to individual producer data, proposed production volumes and scales and financial data. Through the model, the users will receive financial outputs which include capital and operational costs and financial indicators which will guide the user in determining whether the proposed aquaculture project is feasible, and a viable investment opportunity. A high-level overview of the model process can be seen in the figure below.

Figure 9-1: Generic Economic Model Overview



Source: Urban-Econ,2018

The generic economic model can be customised to provide results for individual producers based on selections made with regard to the location of the aquaculture operation (at a provincial level), type of operation (start-up or existing), the scale of operation, type of production system, size, and pricing of the Mozambique tilapia, education level and type of financing that will be used (equity or debt/equity).

9.2. Key Production Assumptions

The generic economic model for Mozambique tilapia was developed using data from various information sources, consultations with various stakeholders and industry experts, and through inputs gathered at two peer-review workshops conducted. The model provides insight into the financial viability of each system, the capital expenditure required to establish a production system, and the recommended selling prices for tilapia. When considering Mozambique tilapia, four systems were considered which include Recirculating Aquaculture Systems (RAS), Pond Systems, Cage Culture and Aquaponics.

9.2.1. Production Assumptions

To develop the generic economic model, specific production assumptions for Mozambique tilapia were identified and utilised. Some key assumptions used can be seen in Table 9-1 below.

Table 9-1: Mozambique tilapia Production Assumptions

Tilapia fingerlings	R 1.75
Maximum Production cycle length	14 months (475 grams)
Survival Rate	95%
Mortality Rate (14 months)	5%
Average Feed price	R 16/kg
Stocking Density	• **RAS/Aquaponics:** 28 kg/m³ • **Pond:** 1.5 kg/m² • **Cage:** 53 kg/ m³

Industry experts recommended the assumptions seen above, however, they may differ from farm to farm. Prices are based on 2017/2018 prices and are subject to change over time.

It is important to note that the results below are unique for each system and based on the results obtained from the generic economic model. The average selling price identified is based on the stakeholder consultations and may not be identical to current market prices. When considering Mozambique tilapia production, it is essential to consider the target market, demand, and a realistic selling price to ensure the project is sustainable.

The land size identified above is calculated based on the minimum infrastructure footprints. As each aquaculture operation will differ according to layout, design, and infrastructure requirements, the land size should be used as a guideline for the minimum size property.

The generic economic model accounts only for the sale of whole tilapia, sold directly from the farm to either a third-party processors, retail markets or directly to consumers looking to purchase whole tilapia. Should processing be required on a farm, additional capital will be required.

9.2.2. Capital Expenditure

The capital expenditure costs for Mozambique tilapia production focused on the establishment of the potential production systems identified for Mozambique tilapia production in South Africa. The capital expenditure is determined by the scale of production, and the selected production cycle length. Some of the key factors to note include the following:

a. **Pre-development costs** for construction phase, concept design, specialist consultations, town planning alignment (zoning, rezoning etc.), and development of bulk infrastructure (roads, installation of electricity to the site, bulk water services etc.) were excluded from the model as this is site specific and not suitable to model at a provincial level,
b. **Land costs** were included should an individual/business not have an existing farm. Based on average farm prices for 2017/2018, a per hectare (ha) rate of R 246 346 was used.
c. **Services** such as the costs of water and electricity were included in the model, and vary between the nine provinces,
d. **Buildings** such as storerooms, offices, cold storage, and a feed room were considered,
e. **Aquaculture system** costs focused on the development of the five production systems,
f. **A storage dam** was included in the capital expenditure costs for selected production systems.
g. **Infrastructure costs** are calculated as a once-off, lump sum amount to be spent in year one, however a producer can choose to phase in production which would split the costs up depending on how the production is phased in.

9.2.3. Operational Expenditure

Operational expenditure, or working capital was determined by looking at the variable costs of production, and fixed costs. Costs can be divided into fixed and variable costs. **Variable costs** include fingerlings, fertilisers (where required), feed, transport, and water costs. It should be noted that it was assumed that aquaculture producers in South Africa are currently not charged for water unless using municipal water sources (DAFF, 2018).

Fixed Costs include costs such as salaries, insurance, electricity, legal/licensing costs, veterinary services, and general expenses (telephone, electricity, health and safety apparel, stationery etc.). Reserve and unforeseen costs have also been included (calculated at 2% of the variable cost total).

9.2.4. Scale of production

From the generic economic model, two production volumes were identified. Firstly, the minimum production volume which indicates at what tonnage a producer would first be profitable. Secondly, the optimal production tonnage was identified, which indicates where the optimal return on investment and profitability is achieved.

9.2.5. Market Information

Tilapia market information was based on industry experts and research conducted. The average farm gate price for Mozambique tilapia ranges from R 30 to R 40 per kilogram in South Africa, however through the results obtained by the generic economic model, specific price ranges have been identified for each production system.

9.3. Mozambique Tilapia: Financial Overview

Using the generic economic models and the assumptions listed in Table 9-2 below, a financial analysis was conducted for Mozambique tilapia.

Table 9-2: Mozambique tilapia Generic Economic Model Inputs

Province	Limpopo
Market	Local
Operational Status	Start-up farmer with no existing farm, facilities, or infrastructure
Skills Level	Formal education (certificate/diploma)
Payback Period	20 years
Financing Option	Debt/Equity with an investor (surety)
Debt Percentage	20%
Weight of fish selected	400 grams (12 months)
Additional Information	• The models exclude the construction phase. The models consider from when production starts • The model excludes consultancy, contactors, and specialised service provider fees, with the exception of veterinary services.

The four production systems considered were the Recirculating Aquaculture Systems (RAS), pond Systems, cage culture and aquaponics. Systems such as ranching, flow-throughs, and raceways were not included in the economic model as these systems were not deemed viable as previously discussed. Each potential production system requires specific infrastructure and facilities and has specific production parameters. Each of the systems are presented in more detail below.

9.3.1. Recirculating Aquaculture Systems

A RAS is known for high operating costs which can be attributed to the high electricity usage for pumping and general operation of the system, as well as feed costs associated with artificial feed sources being the primary food source.

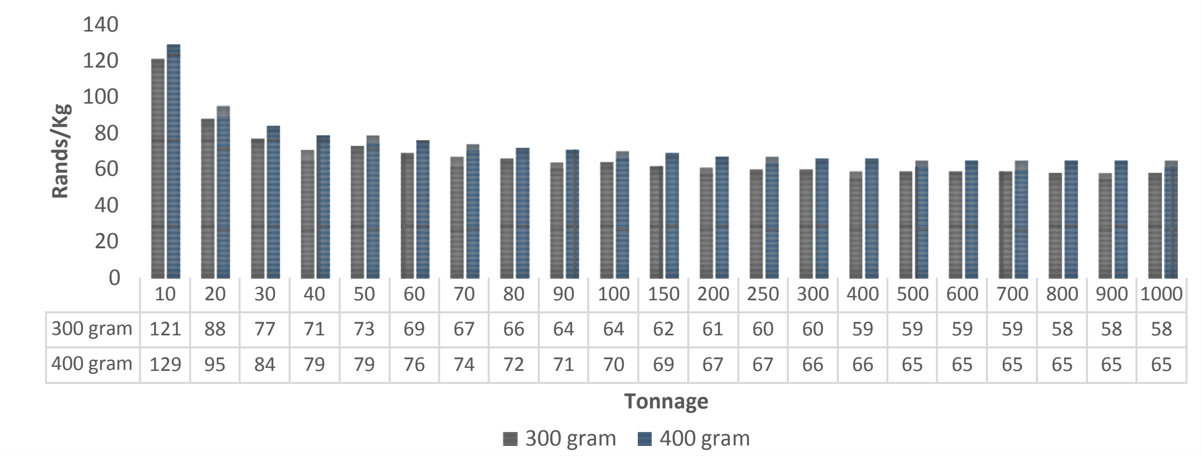
With regards to infrastructure costs, RAS require temperature control measures and heating equipment, as well as tunnel system to assist with reducing electricity consumption and maintaining a constant water temperature. Based on the assumptions presented in Table 9-2 above, the results obtained from the generic economic model for the RAS are discussed in the section below

9.3.1.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Nile tilapia ranges from R 30 to R 40 per kilogram in South Africa.

Figure 9-2 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 9-2: Mozambique Tilapia: RAS Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
300 gram	121	88	77	71	73	69	67	66	64	64	62	61	60	60	59	59	59	59	58	58	58
400 gram	129	95	84	79	79	76	74	72	71	70	69	67	67	66	66	65	65	65	65	65	65

The size of the Mozambique tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **300-gram fish:** R 73/kilogram
- **400-gram fish:** R 79/kilogram

For the purpose of this financial analysis, a 400-gram fish has been selected, and sold at the average price of R 74 per kilogram identified from the graph above.

9.3.1.2. Capital Expenditure

Table 9-3 below provides a summary of the infrastructure and built environment costs required to establish a RAS for Mozambique tilapia production.

Table 9-3: RAS Capital Expenditure

Production Scale	Min Profitable 34 tons	Optimal 530 tons
Purchase Land	R 401 101	R 2 438 296
Infrastructure (Buildings & Tunnels)	R 2 120 500	R 17 042 350

Production Scale	Min Profitable 34 tons	Optimal 530 tons
RAS Infrastructure	R 1 501 265	R 20 128 968
Additional equipment	R 252 480	R 515 004
Total Capital Expenditure	**R 4 445 346**	**R 42 464 318**

9.3.2. Operational Expenditure

Table 9-4 below provides a summary of the operational costs required for Mozambique tilapia production. The operational expenditure is shown for the first year of operation.

Table 9-4: RAS Operational Expenditure for Mozambique tilapia Production (Year 1)

Production Scale	Min Profitable 34 tons	Optimal 530 tons
Variable costs	**R 966 682**	**R 15 033 857**
Tilapia fingerlings	*R 204 920*	*R 3 194 342*
Feed	*R 656 342*	*R 10 231 215*
Consumables – water quality	*R 5 100*	*R 79 500*
Fixed Costs	**R 890 373**	**R 4 581 337**
Total Operational Costs	**R 1 857 055**	**R 19 615 194**

9.3.3. RAS Financial Overview

Table 9-5 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 9-5: Recirculating Aquaculture System Financial Overview

Production Scale	Min Profitable 34 tons	Optimal 530 tons
Financial Indicators		
Total Capital Expenditure	R 5 686 976.69	R 54 269 952.31
Loan Amount – Working Capital	R 1 241 630.90	R 11 805 634.61
Loam Amount - Infrastructure	R 4 445 345.79	R 42 464 317.70
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.06	6.30
Internal Rate Return (IRR)	8%	45%
Net Present Value over 10 years	R 6 000 667.74	R 341 746 840.51
Pay-back period (year)	20	20
Years until profitable	7	2
Production Indicators		
Farm Size (hectares)	1.63	9.9
Number of fingerlings required	9 758	152 112
Number of employees (Year 1)	4	31

The minimum profitable tonnage was identified at 34 tons per annum when selling the fish at identified average selling price of R 74/kg, which does exceed the typical farm-gate price of R 30-40/kg. It is important to consider the costs associated with a RAS, with the estimated capital expenditure of R 5 686 976 is required to meet the minimum profitable tonnage, while the optimal production level of 530 tons per annum would require a capital investment of R 54 269 952 for a start-up producer.

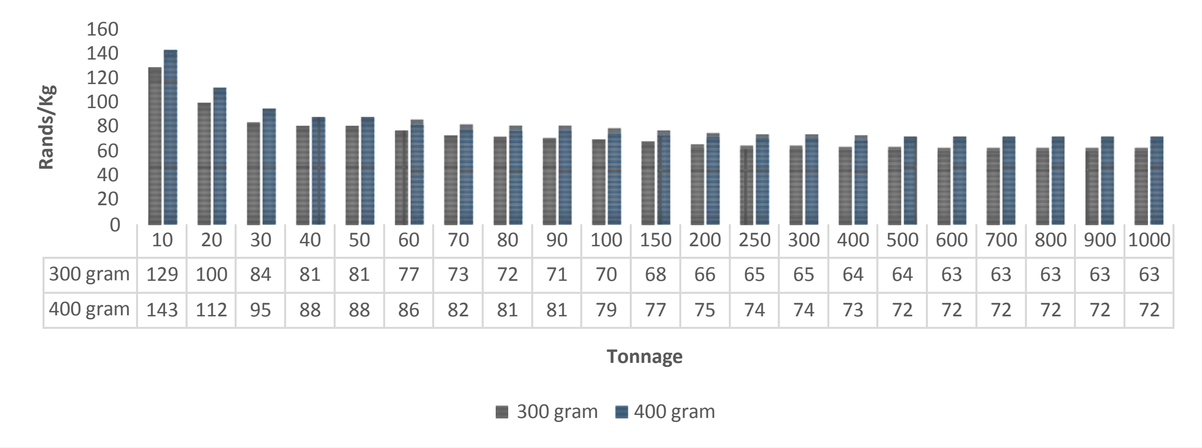
9.3.4. Pond Systems

Based on the assumptions presented in Table 9-2, the following results were obtained from the generic economic model.

9.3.4.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Mozambique tilapia ranges from R 30 to R 40 per kilogram in South Africa, however based on the generic economic model results, it is evident that at these prices, it would not be profitable for a start-up producer to produce Mozambique tilapia. Figure 9-2 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 9-3: Mozambique Tilapia: Pond Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
300 gram	129	100	84	81	81	77	73	72	71	70	68	66	65	65	64	64	63	63	63	63	63
400 gram	143	112	95	88	88	86	82	81	81	79	77	75	74	74	73	72	72	72	72	72	72

The size of the Mozambique tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **300-gram fish:** R 81/kilogram
- **400-gram fish:** R 88/kilogram

For the purpose of this financial analysis, a 400-gram fish has been selected, and sold at the average price of R 83 per kilogram identified from the graph above.

9.3.4.2. Capital Expenditure

Table 9-6 below provides a summary of the infrastructure and built environment costs required to utilise pond culture for Mozambique tilapia production.

Table 9-6: Pond Culture Capital Expenditure

Production Scale	Min Profitable 48 tons	Optimal 744 tons
Purchase Land	R 1 618 333	R 18 917 557
Infrastructure (Buildings & Storage Dam)	R 1 170 250	R 2 585 700
Pond Infrastructure	R 6 225 220	R 84 980 960

Production Scale	Min Profitable 48 tons	Optimal 744 tons
Additional equipment	R 227 005	R 920 036
Total Infrastructure Expenditure	**R 9 253 308**	**R 107 430 453**

9.3.5. Operational Expenditure

Table 9-7 below provides a summary of the operational costs required for Mozambique tilapia production. The operational expenditure is shown for the first year of operation.

Table 9-7: Pond Culture Operational Expenditure for Mozambique tilapia Production (Year 1)

Production Scale	Min Profitable 48 tons	Optimal 744 tons
Variable costs	**R 1 251 397**	**R 19 087 813**
Tilapia fingerlings	*R 219 403*	*R 3 400 746*
Fertiliser	*R 174 000*	*R 2 436 000*
Feed	*R 812 935*	*R 12 600 487*
Consumables – water quality	*R 7 200*	*R 111 600*
Fixed Costs	**R 891 703**	**R 5 426 744**
Total Operational Costs	**R 2 143 101**	**R 24 514 558**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of an aquaponics operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts to assist producers.

9.3.6. Pond Culture Financial Overview

Table 9-8 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 9-8: Pond Culture Financial Overview

Production Scale	Min Profitable 48 tons	Optimal 744 tons
Financial Indicators		
Total Capital Expenditure	R 11 396 409.25	R 131 945 011.47
Loan Amount – Working Capital	R 2 143 101.35	R 24 514 558.14
Loam Amount - Infrastructure	R 9 253 307.50	R 107 430 453.33
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.05	3.09
Internal Rate Return (IRR)	8%	27%
Net Present Value over 10 years	R 11 930 726.83	R 462 577 793.26
Pay-back period (year)	20	20
Years until profitable	8	2
Production Indicators		
Farm Size	6.6 hectares	76.8 hectares
Number of fingerlings required	10 448	161 940
Number of employees (Year 1)	3	34

The minimum profitable tonnage was identified at 48 tons per annum when selling the fish at the average selling price of R 83/kg, which exceeds the typical farm gate price of R 30-40/kg. It is important to consider the costs associated with a pond system, with an estimated R 11 396 409 required to support the minimum profitable tonnage, while the optimal production level of 744 tons per annum would require a capital investment of R 131 945 011 for a start-up producer.

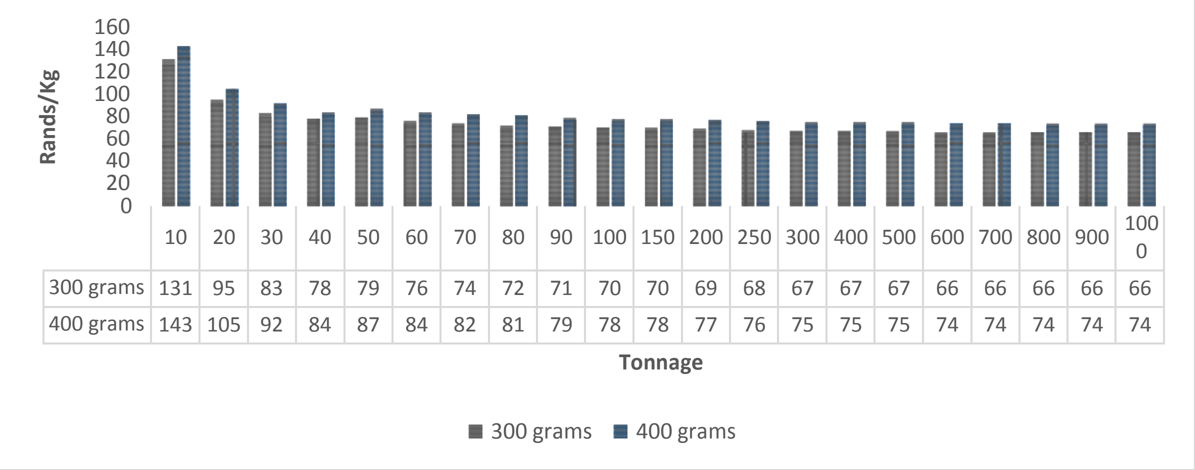
9.3.7. Aquaponics Systems

Aquaponics is one of the more profitable production system, specifically as producers benefit from two income streams (vegetables and fish). The generic economic model is based on the production of leafy green vegetables (lettuce, spinach, pak choi and basil) as these are the easiest to grow in comparison to vegetables such as tomatoes, carrots etc. It is assumed that the plant production will be phased in over the first year.

9.3.7.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Mozambique tilapia ranges from R 30 to R 40 per kilogram in South Africa, however based on the generic economic model results, it is evident that at these prices, it would not be profitable for a start-up producer to produce Mozambique tilapia. Figure 9-3 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 9-3: Mozambique Tilapia: Aquaponics Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
300 grams	131	95	83	78	79	76	74	72	71	70	70	69	68	67	67	67	66	66	66	66	66
400 grams	143	105	92	84	87	84	82	81	79	78	78	77	76	75	75	75	74	74	74	74	74

The size of the Mozambique tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **300-gram fish:** R 79/kilogram
- **400-gram fish:** R 87/kilogram

For the purpose of this financial analysis, a 400-gram fish has been selected, and sold at the average price of R 83 per kilogram identified from the graph above.

9.3.7.2. Capital Expenditure

Table 9-9: Aquaponics Capital Expenditure

Production Scale	Min Profitable 64 tons	Optimal 699 tons
Purchase Land	R 732 009	R 4 850 279
Infrastructure (Buildings & Tunnels)	R 5 928 815	R 46 924 359
Aquaponics system	R 3 705 219	R 33 806 706
Additional equipment	R 537 028	R 1 550 624
Total Capital Expenditure	**R 11 634 244**	**R 94 075 166**

9.3.7.3. Operational Expenditure

Table 9-10 below provides a summary of the operational costs required for Mozambique tilapia production. The operational expenditure is shown for the first year of operation.

Table 9-10: Aquaponics Operational Expenditure for Mozambique tilapia Production (Year 1)

Production Scale	Min Profitable 64 tons	Optimal 699 tons
Variable costs	**R 1 639 506.92**	**R 16 129 046**
Tilapia fingerlings	*R 292 537*	*R 2 893 377*
Feed	*R 1 083 913*	*R 10 720 576*
Consumables – water quality	*R 9 600*	*R 94 950*
Hydroponic Net Pots (5% pa replacement)	*R 3 237*	*R 32 019*
Additional (chemicals/nutrients etc)	*R 6 600*	*R 7 920*
Seedlings	*R 194 239*	*R 1 921 145*
Fixed Costs	**R 1 408 988**	**R 7 831 702**
Total Operational Costs	**R 3 048 494**	**R 23 960 749**

As previously mentioned, feed costs are a major factor to consider when looking at the profitability of an aquaponics operation. Producers should carefully plan and implement feeding programmes to ensure optimal consumption and minimal waste of the feed. Feed suppliers should also be encouraged to assist farmers by considering bulk order discounts. In addition to bulk feed prices, producers should identify bulk seedling suppliers, or alternatively investigate the feasibility of establishing their own growing facility for seedlings. Packaging and labelling required for the vegetables has not be included in the costing above, and should be considered by producers, specifically based on the target market requirements.

9.3.7.4. Aquaponics Financial Overview

Table 9-11 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 9-11: Aquaponics Financial Overview

Production Scale	Min Profitable 64 tons	Optimal 633 tons
	Financial Indicators	
Capital Expenditure	R 14 529 346.92	R 116 641 524.83
Loan Amount – Working Capital	R 2 895 102.27	R 22 566 358.83
Loam Amount - Infrastructure	R 11 634 244.66	R 94 075 166.01
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.01	2.68
Internal Rate Return (IRR)	7%	24%

Production Scale	Min Profitable 64 tons	Optimal 633 tons
Net Present Value over 10 years	R 14 713 359.28	R 313 154 254.61
Pay-back period (year)	20	20
Years until profitable	8	3
Production Indicators		
Farm Size	2.9 hectares	19.7 hectares
Number of fingerlings required	13 930	137 780
Number of employees (Year 1)	8	61

The minimum profitable tonnage was identified at 64 tons per annum when selling the fish at the average selling price of R 83/kg, which exceeds the typical farm-gate price of R 30 -40 /kg. It is important to consider the costs associated with aquaponics, with an estimated R 14 529 346 required to support the minimum profitable tonnage, while the optimal production level of 633 tons per annum would require a capital investment of R 116 641 524 for a start-up producer. The costs associated with establishing and operating an aquaponics system are predominantly linked to the infrastructure development and operational costs of feed, and seedlings.

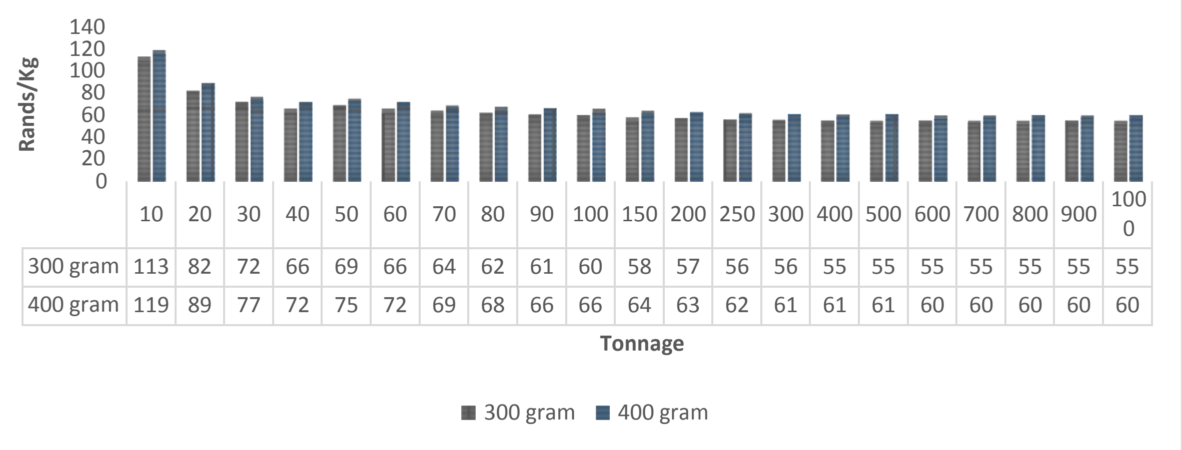
9.3.8. Cage Culture

Cage culture as a production method, is vastly different from other production systems, as it is not as intensive, and requires fewer operating costs specifically when looking at electricity, and water costs, as well as the need for the producer to purchase land, as these systems are water based, and require minimal land. Feeding programmes and costs will also vary considerably in comparison with the other systems discussed.

9.3.8.1. Price Sensitivity

The generic economic models clearly identify the key impact pricing of the fish (Rands/kilogram) plays in determining the minimum and maximum profitable scales of production. The average farm gate price for the Mozambique tilapia ranges from R 30 to R 40 per kilogram in South Africa. Figure 9-2 below identifies the minimum selling price at the various production volumes, ranging from 10 to 1000 tons per annum.

Figure 9-4: Mozambique Tilapia: Cage Culture Price Sensitivity Analysis



	10	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	900	1000
300 gram	113	82	72	66	69	66	64	62	61	60	58	57	56	56	55	55	55	55	55	55	55
400 gram	119	89	77	72	75	72	69	68	66	66	64	63	62	61	61	61	60	60	60	60	60

The size of the Mozambique tilapia being sold plays a major role in the profitability of an operation and the selling price that should be targeted. While plate sized fish are generally more popular for the general consumer, growing the tilapia to larger weights (i.e. 300 grams or more) is less profitable than selling them at smaller sizes. There has been an informal market in South Africa identified for smaller tilapia, however, this market is informal and is currently being researched and analysed. For example, if producing 50 tons of tilapia, the following selling prices would need to be achieved to be profitable:

- **300-gram fish:** R 69/kilogram
- **400-gram fish:** R 75/kilogram

For the purpose of this financial analysis, a 400-gram fish has been selected, and sold at the average price of R 69 per kilogram identified from the graph above.

9.3.8.2. Capital Expenditure

Table 9-12 below provides a summary of the infrastructure and built environment costs required to utilise cage culture for Mozambique tilapia production in South Africa.

Table 9-12: Cage Culture Capital Expenditure

Production Scale	Min Profitable 34 tons	Optimal 774 tons
Purchase Land	R 250 964	R 256 027
Infrastructure (Buildings)	R 1 099 832	R 2 529 270
Cage Culture system	R 92 607	R 1 926 975
Additional equipment	R 367 789	R 1 294 383
Total Capital Expenditure	**R 1 823 693**	**R 6 032 856**

9.3.8.3. Operational Expenditure

Table 9-13 below provides a summary of the operational costs required for Mozambique tilapia production. The operational expenditure is shown for the first year of operation.

Table 9-13: Cage Culture Operational Expenditure for Mozambique tilapia Production (Year 1)

Production Scale	Min Profitable 34 tons	Optimal 774 tons
Variable costs	**R 996 682**	**R 22 379 418**
Tilapia fingerlings	*R 204 920*	*R 4 755 351*
Feed	*R 656 342*	*R 15 230 997*
Consumables – water quality	*R 5 100*	*R 118 350*
Fixed Costs	**R 783 420**	**R 4 796 416**
Total Operational Costs	**R 1 750 103**	**R 27 175 834**

9.3.8.4. Cage Culture Financial Overview

Table 9-14 below provides an overview of the capital expenditure required, as well as financial indicators and a high-level overview of the production requirements including land size, estimated number of fingerlings required in month one (1), and the estimated number of employees required in the first year of production.

Table 9-14: Cage Culture Financial Overview

Production Scale	Min Profitable 34 tons	Optimal 774 tons
Financial Indicators		
Total Capital Expenditure	R 3 028 655.44	R 22 877 033.75
Loan Amount – Working Capital	R 1 204 961.63	R 16 844 176.99
Loam Amount - Infrastructure	R 1 823 693.81	R 6 032 856.77
Interest Rate	8.25%	8.25%
Profitability Index (PI)	1.19	18.81

Production Scale	Min Profitable 34 tons	Optimal 774 tons
Internal Rate Return (IRR)	10%	87%
Net Present Value over 10 years	R 3 613 588.57	R 430 214 210.14
Pay-back period (year)	20	20
Years until profitable	4	2
Production Indicators		
Farm Size	1.02 hectares	1.04 hectares
Number of fingerlings required	9 758	226 445
Number of employees (Year 1)	3	36

The minimum profitable tonnage was identified at 34 tons per annum when selling the fish at the average selling price of R 69/kg, which exceeds the typical farm-gate price of R 30-40/kg. It is important to consider the costs associated with cage culture, with an estimated R 3 028 655 required to meet the minimum profitable tonnage, while the optimal production level of 774 tons per annum would require a capital investment of R 22 877 033 for a start-up producer. The costs associated with establishing and operating a cage culture operation are lower than any of the other systems, which is linked to less infrastructure requirements, much lower day-to-day operational costs as well as a reduced demand for land, electricity, and additional expenses such as fertilisers or tunnels.

9.3.9. Mozambique Tilapia Financial Analysis Summary

Based on the financial analysis conducted for each of the four (4) production system above, it is evident that each system offers advantages and disadvantages for producers. The table below provides a high-level summary of the capital expenditure required for the minimum profitable tonnage when selling the fish at the identified average selling price, and the estimated return on investment.

Table 9-15: Mozambique Tilapia Summary: Production Systems Financial Overview

	RAS	Pond	Cage	Aquaponics
Tonnage	34	48	34	64
Selling Price	R 74/kg	R 83/kg	R 69/kg	R 83/kg
Capital Expenditure	R 5 686 976	R 11 396 409	R 3 028 655	R 14 529 346
IRR	8%	8%	7%	10%

From a financial aspect, it is clear that cage culture requires the lowest capital expenditure of R 3 028 655 and also offers producers the lowest operational costs. However, although economically attractive the system comes with several challenges, namely identifying and securing a suitable body of water, as well as maintaining the cage culture system to ensure the water body conditions are maintained and does not negatively impact the surrounding natural environment. The cage culture system offers producers the opportunity to offer competitive pricing with an average of R 69/kg required when producing 34 tons per annum.

The Pond and Aquaponics systems are considered to be the most capital-intensive systems, with the initial capital expenditure required being high, specifically for aquaponics. The operational costs associated with these system have a major impact on the minimum profitable farm gate prices that are required when compared with the other systems. The RAS system requires an average farm gate price of R 74/kg if producing a minimum of 34 tons per annum. Although Aquaponics is the most capital-intensive systems it offers producers two income streams and a more stable income from month one of production. Pond culture systems offer an affordable solution for producers with much lower operational expenses, and also the ideal culturing system for the Mozambique tilapia.

The higher selling prices required for RAS, aquaponics and pond systems impacts on the competitiveness of the producer, specifically as the average farm gate price identified by stakeholders was around R40/kg. Pricing has a major impact on the profitability of an aquaculture operation, and for producers to be profitable, careful consideration of the operational costs specifically feed, labour, fingerlings and day to day costs is required. Based on the results in the table above, cage culture, pond and RAS are the most suitable system for Mozambique Tilapia. When selecting a production system, careful consideration is required not only for the site selection, but also establishing an off-take market that can pay producers the prices required for their operations to be profitable. The Mozambique tilapia generic economic model focused on primary production, however, producers should investigate not only Mozambique tilapia production, but also value-addition/processing activities as this would increase the revenue that can be achieved by a single producer.

9.4. Mozambique Tilapia Cost-Benefit Analysis

Table 9-16 below shows a high-level cost benefit analysis for Mozambique tilapia, based on the profitability index (PI) which is used as the cost benefit ratio. The analysis considers the four (4) production systems, at the minimum profitable tonnage and optimal production volumes as identified in the section above.

Table 9-16: Mozambique Tilapia: Cost Benefit Analysis

	RAS	Pond	Cage	Aquaponics
Minimum Profitable Tonnage				
Market price (R/kg)	R 74/kg	R 83/kg	R 69/kg	R 83/kg
Tons produced/annum	34	48	34	64
Profitability Index (PI)	1.06	1.05	1.19	1.01
Internal Rate of Return (IRR)	8%	8%	7%	10%
Employees required (Year 1)	4	3	3	8
Optimal Tonnage				
Market price (R/kg)	R 74/kg	R 83/kg	R 69/kg	R 83/kg
Tons produced/annum	530	744	774	633
Profitability Index (PI)	6.30	3.09	2.68	18.81
Internal Rate of Return (IRR)	45%	27%	87%	24%
Employees required (Year 1)	31	34	36	61

It should be noted, as mentioned previously, Mozambique tilapia is slow growing, and this analysis was conducted for fish weighing 400 grams (9 months), which is considered a plate sized fish, and is popular on the market. Based on the table above, when considering the minimum profitable tonnage identified in the various systems, cage culture is profitable at the average selling price of R 69/kg when producing a minimum of 34 tons per annum, followed by RAS (R 74/kg).

Each system offers a number of employment, specifically at the higher tonnages, where more specialised and skilled employees can be used as the operation will be able to cover their salaries. At the lower tonnages, it is recommended that labour costs are kept to a minimum to ensure the operation is profitable, thus all systems offer between three (3) and four (4) jobs in year one of operation. The most labour-intensive systems at the higher tonnages is the Aquaponics, Pond and Cage culture systems.

10. Nile and Mozambique Tilapia Best Case Scenario

Through the generic economic models, it is possible to look at "Best Case Scenarios" for each of the potential production systems at a provincial level. To do this, the following categories and criteria were used to assess the economic models.

a. **Selling weight:** The selected weigh for Nile tilapia was 465 grams (8 months), and Mozambique tilapia selected weight was 400 grams (12 months), which are considered plate size fish.

b. **Minimum Tonnage required for each production cycle:** The minimum tonnage was identified to determine the minimum tonnage that a tilapia producer needs to produce to be profitable. Profitability was measured by looking at the Profitability Index (PI), which should be one (1) or more.

c. **Price:** The farm gate price received for the tilapia has a major impact on the profitability and sustainability of the aquaculture operation. The minimum recommended selling price differs for each production system and is affected by the annual production volume selected.

d. **Finance Type:** The generic economic model provides three financing options for producers, however for this analysis the **debt/equity** finance option was selected with a 20% debt ratio. This assumes that a producer contributes 20% of their assets and receives funding for the remaining 80%.

When making use of the generic economic model for the Nile and Mozambique tilapia it should be noted that the figures and analysis discussed below are based at a provincial level and were obtained with the general assumptions used in the economic model. While at a provincial level a system and tonnage may show a positive or negative return on investment or profitability index, this may differ at a site-specific level depending on the site temperatures and conditions, water quality and temperature, access to markets and access to input supplies, which all have a significant impact on the profitability and viability of an aquaculture operation.

10.1. Nile Tilapia Best Case Scenarios

When making use of the generic economic models for Nile tilapia, it is possible to identify the minimum and maximum viable size (months/grams) for Nile tilapia as well as recommended pricing and target market for each of the four systems considered to be viable for Nile tilapia in South Africa. The table below provides an overview of the minimum annual tonnage required in each province at the average selling price

Table 10-1: Nile Tilapia: Best Case Scenario Summary

EC	R 62/kg 146 tons	R 32/kg 44 tons	R 27/kg 63 tons	R 29/kg 47 tons
KZN	R 62/kg 146 tons	R 32/kg 44 tons	R 27/kg 63 tons	R 29/kg 47 tons
GP	R 62/kg	R 32/kg	R 27/kg	R 29/kg

	RAS	Pond	Cage	Aquaponics
	146 tons	44 tons	63 tons	47 tons
WC	R 62/kg	R 32/kg	R 27/kg	R 29/kg
	146 tons	44 tons	63 tons	47 tons
NC	R 70/kg	R 35/kg	R 30/kg	R 30/kg
	213 tons	80 tons	89 tons	188 tons
LP	R 62/kg	R 32/kg	R 27/kg	R 29/kg
	190 tons	48 tons	75 tons	67 tons
MP	R 62/kg	R 32/kg	R 27/kg	R 29/kg
	190 tons	48 tons	75 tons	67 tons
NW	R 62/kg	R 32/kg	R 27/kg	R 29/kg
	190 tons	48 tons	75 tons	67 tons
FS	R 62/kg	R 32/kg	R 27/kg	R 29/kg
	190 tons	48 tons	75 tons	67 tons

Based on the table above, pond, cage and aquaponics are the most profitable systems for Nile tilapia production, with RAS being the least profitable system based on the average selling price required for an operation to be profitable and the minimum profitable tonnage that has been identified. The Northern Cape, although profitable for Nile tilapia production, is the least profitable province, which can be attributed to the distance to inputs and markets as well as the climatic extremes experienced in the province. The remaining eight (8) provinces produced similar results, with the Eastern Cape, Western Cape, KwaZulu Natal and Gauteng showing slightly more profitable operations.

10.2. Mozambique Tilapia

The table below provides an overview of the minimum annual tonnage required in each province at the average selling price.

Table 10-2: Mozambique Tilapia Best Case Scenario Summary

	RAS	Pond	Cage	Aquaponics
EC	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	36 tons	40 tons	48 tons	36 tons
KZN	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	36 tons	40 tons	48 tons	36 tons
GP	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	36 tons	40 tons	48 tons	36 tons
WC	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	36 tons	40 tons	48 tons	36 tons
NC	R 80/kg	R 87/kg	R 75/kg	R 90/kg
	221 tons	244 tons	227 tons	158 tons
LP	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	34 tons	48 tons	34 tons	64 tons
MP	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	34 tons	48 tons	34 tons	64 tons
NW	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	34 tons	48 tons	34 tons	64 tons
FS	R 74/kg	R 83/kg	R 69/kg	R 83/kg
	34 tons	48 tons	34 tons	64 tons

Based on the table above, Cage culture and RAS are the most profitable systems for Mozambique tilapia when considering the average selling price and minimum profitable annual tonnage. The Northern Cape, although profitable for Mozambique tilapia production, is the least profitable province, which can be attributed to the distance to inputs and markets as well as the climatic extremes experienced in the province. Out of the remaining eight (8) provinces, the Eastern Cape, Western Cape, KwaZulu Natal and Gauteng provinces showed a higher return on investment when using pond culture and aquaponics, while cage culture and RAS were more profitable in the likes of Limpopo and Mpumalanga.

Overall, from Table 10-1 and Table 10-2 above, it is evident that Nile tilapia is the far more profitable species out of the two, specifically when looking at the average selling price required for operations to be profitable as well as the minimum tonnages required for producers to be profitable.

As previously mentioned, the success of Nile tilapia in aquaculture operations is attributed to its faster growth rate, as well as larger size achieved at the end of the nine (9) month production cycle. Based on these results, it is evident that increased research is required to further develop the Mozambique tilapia to ensure the growth rates can be improved upon, thus making it a more profitable species for aquaculture operations. As Nile tilapia is currently not produced widely due to its alien invasive status, efforts should be made to allow for the controlled and monitored culturing of Nile tilapia in South Africa to ensure growth and development of the local tilapia industry.

11. Conclusion and Recommendations

This section provides conclusions and recommendations based specifically on the production aspect, including systems for Nile and Mozambique tilapia. In addition, recommendations based on the market assessment, and SWOT analysis are included.

11.1. Conclusion

Nile and Mozambique tilapia are often referred to as the 'aquatic chicken' due to its popularity and well-known status in the aquaculture industry. The hardiness of the fish and adaptability to a wide range of culture systems have resulted in tilapia species being one of the most preferred species for aquaculture production. tilapia produces have exceptional quality of meat that has good market acceptance. Currently, most registered tilapia farms in South Africa are in the Gauteng, Limpopo, Mpumalanga, and North-West provinces in that order. Furthermore, the majority of tilapia farmers operate at a small-scale, and typically make use of recirculation and pond culture systems. Some of the major challenges faced by tilapia producers in South Africa include legislative and regulatory compliance, unsuitable environmental temperature regime, underdeveloped value chain, high production costs, and the need for product development and marketing strategies to position it competitively against imported tilapia products.

To reduce the costs and the likelihood of operating an unsuccessful production system, certain measures must be taken into consideration. This includes ensuring good farm management practices, selection of a suitable production site (with appropriate climate, soil, topography, water quality and quantity, etc.), accurate system design, adequate skills, and training in operating the system, good marketing strategy; and sound product distribution logistics, etc. The following factors were identified as optimal operational requirements for tilapia aquaculture to be profitable:

I. Hatchery or access to fingerlings,
II. Mono sex fry,
III. Appropriate water temperature, quality, and quantity,
IV. Economies of scale and consistent volume of production,
V. Good access to production inputs and support services,
VI. Value-addition or processing,
VII. Access to market (both formal and informal), and
VIII. Disease management.

The various culture systems considered for tilapia production in this report are the RAS, aquaponics, pond culture, raceways, and the flow-through system. However, the review of literatures reveals that the technology used within the raceway and the flow-through systems are not appropriate for commercial aquaculture of tilapia. This is mainly due to issues concerning the regulation of water temperature and the water current produced when these two culture systems are used.

Although tilapia culture is generally possible throughout most lowland areas of South Africa by using various modern aquaculture technology, it is still important to determine the most thermally efficient areas to culture the species under extensive systems (e.g. ponds), with little or no technology application. While this has been done at a provincial level, it should also be conducted at a site-specific level as environmental and production differ between every aquaculture operation.

It can be seen from the financial analysis that KwaZulu Natal, the Eastern Cape and Western Cape show the highest levels of profitability for Nile Tilapia in all four (4) systems, while for Mozambique Tilapia, these provinces are more profitable when using pond culture or aquaponics. Limpopo and Mpumalanga are more suited for Mozambique Tilapia when using RAS or Cage culture. The Northern Cape province offers the lowest economic returns on the production systems which can be attributed to the higher temperatures, evaporation rates and distance to obtain inputs and access markets. The generic economic model highlights that Nile tilapia is more profitable than Mozambique tilapia in South Africa, specifically when using aquaponics, cage, and pond culture. While all the production systems are profitable in South Africa, careful consideration is required before selecting a production system, as the feasibility and profitability of a system is influenced by the location of a project, scale of production and target market, and selling price achieved.

11.2. Recommendations

Based on the study conducted, the following recommendations have been made:

I. Support the development of the Tilapia value chain, looking specifically at access to feed, feed costs and the quality of feed available in South Africa,
II. Trials and/or pilot projects should be conducted on culturing sea run Mozambique tilapia,
III. Research and Development should be focused on reducing the lengthy production cycle of Mozambique tilapia and increasing its growth rate,
IV. Streamlining of the permit and regulatory process would assist producers in becoming operational in a shorter timeframe,
V. Develop testing and regulatory standards and guidelines to align the South African tilapia industry with the EU and USA market standards and regulations,
VI. Streamline regulatory and permit application process, specifically for Nile tilapia. This would assist with increasing production and growing the industry,
VII. Research and Development is required to improve technology available to tilapia producers in South Africa to reduce the capital and operational expenditure, specifically for RAS systems,
VIII. Research and Development should be done on the use of additional production systems in South Africa, such as mixed cell raceways,
IX. Regulate Tilapia imports entering and being distributed through to South Africa to protect the local market and encourage producers to expand current production,
X. Improved co-ordination and communication between Tilapia producers, stakeholders and government would assist with the development and growth of the industry,
XI. The Tilapia generic economic models should be updated annually to ensure the assumptions and costings are accurate. The updates will ensure the long-term use and sustainability of the generic economic models, and
XII. Strategic guidelines for tilapia production should be developed, and should cover:
    a. Production guidelines and information,
    b. Post Production and marketing regulations and standards,
    c. Permits and regulatory information (National and Provincial level),
    d. Environmental risks posed by Tilapia.

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